CEROS

NATIONAL DEFENSE CENTER OF EXCELLENCE FOR RESEARCH IN OCEAN SCIENCES

FINAL TECHNICAL REPORT

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CEROS Point of Contact: William A. Friedl
(808) 327-4310
73-4460 Queen Kaahumanu Highway, Suite 111
Kailua-Kona, HI 96740
CEROS Website: http://www.ceros.org

EXECUTIVE SUMMARY

In February 1993, DoD technical needs, combined with ocean technology capability in Hawaii, yielded the National Defense Center of Excellence for Research in Ocean Sciences (CEROS). CEROS was established through a grant from the Defense Advanced Research Projects Agency (DARPA) to the High Technology Development Corporation (HTDC), an agency of the State of Hawaii attached to the Department of Business, Economic Development and Tourism (DEBDT). CEROS was funded

> ". . . for the purpose of conducting research and development activities of interest to the Department of Defense . . . and . . . to support and stimulate a broad spectrum of research in ocean science in the State of Hawaii."

DARPA awarded MDA 972-94-1-0010 for $5,000,000 to HTDC for CEROS in May 1994. Total funding to CEROS for Grant No. MDA 972-94-1-0010 was approximately $18,738,000. This grant supported a core program of thirty-nine projects involving nineteen prime contractors during CEROS FY94, FY95, and FY96. All contracts were complete by the end of June 1999. This report describes the work done under the 1994 grant. Following is an outline of individual projects in the core program, and more detailed information is available in chapters 2 through 27 of this report.

Alliant Techsystems, Inc., now Raytheon Systems Company, Mulkilteo, Washington. *High-Resolution Bottom-Penetrating Acoustic Sensors and Signal Processing Algorithms for Reduction of False-Alarm Probability in UXO Hunting.*

This project demonstrated increased resolution and reduced false alarm rates for a synthetic aperture sonar (SAS) added to the HAWAII MR-1, a towed sonar array and data processing system owned by the Hawaii Institute of Geophysics. SAS technology uses the forward motion of a small physical array to synthesize a much larger array. The long synthesized array produces a much higher along-track resolution and signal to noise ratio (contrast) than that of the physical array alone. Using SAS technology, the along-track resolution can be made constant independent of frequency and range. As a consequence, lower operating frequencies (lower absorption) can be used in an SAS to increase range or to penetrate the bottom without compromising resolution. This is the first known use of SAS techniques to image buried objects.

During the first year of funding, the data quality suffered from excessive towbody movements caused by the ship's movements. In subsequent years, the towbody was reconfigured to operate either as a heavy tow, or as a neutral tow that decouples the towbody from the ship's motions in heavier seas.

The system was improved significantly from FY94 to FY96. The improvements allow forming a SAS image equivalent to a 9m array which is a 6-fold improvement over the original 1.5m array. The FY96 system gives more resolution, more contrast, and detection of the deepest buried cylinder (2m). The SAS images achieve the 20cm limit set by the array spacing. The simulation results predict "resonances" in man-made cylindrical objects. With the SAS system it is possible to detect these resonances for the targets on the bottom.

The technology has wide potential application and relates directly to emerging programs in mine countermeasure technology at the Office of Naval Research and advanced sonar development at ARPA. Hawaii involvement is very high and potential residual benefits to Hawaii

are great. The original contract was let to Alliant Techsystems which was purchased by Hughes Aircraft Company in March 1997. In December 1997 Hughes merged with Raytheon Systems Company.

Aquaculture Technology, Inc. Honolulu, Hawaii. *Naturally Occurring Antibodies From Marine Algae Chaetoceros*

In a breakthrough discovery, Aquaculture Technology, Incorporated (ATI) has isolated some naturally-occurring antibacterial compounds from the marine algae *Chaetoceros spp.*. Aquaculturists had observed that certain algae could be maintained in a pure culture without the addition of antibiotics. Dr. Wang hypothesized that something in the alga itself acted as an antibiotic to prevent growth of other organisms. He identified several polyunsaturated fatty acids in the chemical composition of *Chaetoceros spp.*. He then demonstrated that these compounds are effective against *Vibrio vulnificus, Listeria monocytogenes,* methicillin-resistant *Staphylococcus aureas,* vancomycin-resistant *Enterococcus* and other bacteria in *in vitro* tests. ATI contacted Tripler Army Medical Hospital in Honolulu and Walter Reed Army hospital in Washington to review research methods and results.

The discovery of new antibacterial substances from marine algae provides at least two avenues for commercialization: to license the production of the antibiotic, and to supply the algae to the pharmaceutical company for the production of antibiotics.

These compounds are nearly impossible to synthesize, so large quantities of *Chaetoceros spp.* will need to be grown for drug production. Dr. Wang developed a revolutionary open system for large-scale production of marine microalgae without innoculation. The continuous marine algae production system will have applications beyond the supply of algae for medical purposes. Marine microalgae provide many important industrial products like food pigments and biosurfactants with billion dollar world markets.

Detection Limit Technologies, Inc, Kailua, Hawaii. *Design And Deployment Of A Fiber-Optic Based Autonomous Buoy For In-Situ Monitoring Of pH, pCO2, Temperature, O2, And Water Quality In Seawater (Phase II); Solution+ In-Situ Ocean Sediment Chemical Analyzer*

Detection Limit Technologies, Inc. (DLT) demonstrated for the first time the ability to detect oxygen in seawater based on the molecular composites incorporating tailored excited states of transition metal complexes and thin mono and multilayer films. To achieve this breakthrough technology, DLT developed a unique metal coating for the sensor. DLT developed a new palladium-porphyrin complex, immobilized a platinum porphyrin in a film of polycarbonate on a fused silica surface, and demonstrated oxygen sensitivity behavior of the coating. The dye is not susceptible to photobleaching and is particularly amenable to low-power, diode-based laser sources that would be required to use the instrument on a robust, remote ocean data buoy. This development allowed DLT to use Raman spectrographic techniques to measure oxygen. The original plan to deploy and test instruments on buoy purchased from Woods Hole Oceanographic Institution was modified because of delays at Woods Hole in buoy development. DLT demonstrated alternative test scheme using instruments deployed from Makai Research Pier, Waimanalo, O'ahu in December 1995.

In FY96, DLT improved the *Solution* instrument by adding a fluorescence mode to the Raman system. The improved instrument, trademarked *Solution+,* incorporated an ultraviolet excitation capability that allowed collection of Raman and fluorescence data simultaneously. The fluorescent capability increased the instrument's capability to detect additional classes of hydrocarbons (e.g. phenols) and to monitor and map site contamination directly using sediment

probes. DLT developed stable Raman surfaces that could detect TCE in the 10 ppm range without interference from fluorescence, and to detect particular heavy metals down to 50 ppB. The *Solution+* is a rugged and versatile instrument with applications in environmental monitoring, process control and teaching. DLT miniaturized the probe of the *Solution+* to fit into the SPAWARSYSCEN cone penetrometers to assess environmental contamination at DoD sites in an efficient and cost-effective manner. DLT has used CEROS developmental support to develop a variety of specialized measurement and control instruments based on the *Solution* and *Solution +* prototypes. DLT is actively marketing the commercial versions of the *Solution* and *Solution +* instruments for diverse applications.

Gateway Technology International, Inc. Honolulu, HI. *HIRADSIM Workstation Development Project. Continuation of Existing Work Advanced HIRADSIM Small Target, Time Domain, Maritime Radar Mode.*

Hawaii Radar Simulator (HIRADSIM) is an engineer's radar detection slant tracker design tool. The HIRADSIM model runs on a IIP UNIX or an HP 712/60 workstation and is mostly written in C+ except for the radar cross-section model, which is written in FORTRAN. The output of the model provides a radar engineer with the ability to make predictions of received radar-signal strength as a function of various marine environments including rain and sea state. The model is a basic research tool to help design better radar-detection technology for the small targets like instrument masts (periscopes), small boats, and ships that have special wake considerations. Gateway Technologies International Incorporated (GTII) validated the HIRADSIM model and demonstrated the model's effectiveness on a workstation platform, to realize the advances made in radar sensor data fusion and environmental modeling in the FY93 program. Work focused on practical applications of HIRADSIM and included comprehensive tests, evaluations, and demonstrations for qualified technical observers. GTII developed the graphical user interface and integrated it in the workstation. HIRADSIM was tested at the Pacific Missile Test Facility in conjunction with large-scale radar evaluations conducted by NRaD, San Diego laboratory. The workstation-oriented, time domain radar simulator has been improved with a larger area of consideration and reduced computational time (4 to 5 times faster). HIRADSIM demonstrates credibility and internal program capability for GTII and CEA Technologies, Inc., and commercialization is possible for specific applications. GTII and CEA Technologies, Inc. met both the technical and commercial objectives of this effort, namely developing an advanced radar simulator.

Innovations Hawaii, Inc. Honolulu, Hawaii. *Extended-Source Apparent Motion (E-SAM) Lighted Signals for Protection of the Marine Environment*

Innovations Hawaii, Inc. built and tested a pre-production prototype range light system based on the Extended-Source Apparent Motion (E-SAM) principle. E-SAM features a vertically-oriented array of sequentially operated optical flashtubes mounted on a central support tower (two towers for a range light system). When the lights are flashed in sequence they look like a moving light to a human observer, a phenomenon called Apparent Motion. This makes the light extremely conspicuous to the observer, particularly in the peripheral vision field.

Field tests conducted by Innovations Hawaii with experienced mariners as human observers at the entrance to Honolulu Harbor demonstrated that the E-SAM system is highly conspicuous, even against dense background shore lighting. Innovation Hawaii's use of flashtubes in the E-SAM also demonstrated a superior technological advance over the incandescent bulbs used by the Coast Guard in the majority of aids to navigation.

In this follow-on project also supported in FY93, Innovations Hawaii improved the design, assembled a pre-production working model, and tested it in the field. The E-SAM system's superior conspicuity was clearly demonstrated in the tests. Although the Coast Guard has professed no intention to pursue development of extended source light systems, Innovations

Hawaii presented plans to discuss their specific results with Coast Guard technical representatives with a goal of further demonstrations of the E-SAM system. Innovations Hawaii provided a complete project summary to the Coast Guard R&D Center, Gorton, CT and the Coast Guard Office of Engineering in Washington, DC. There are several DoD applications for E-SAM technology, including mobile range or marking systems, mine field marking or navigation aids, and troop guidance on land. A provisional patent is being maintained.

KnappEngineering, Inc. dba Structural Solutions, Inc. Aiea, Hawaii. *Finite Element Design of Cables*

Knapp Engineering, Inc, doing business as Structural Solutions, developed the first finite element-based computer-aided design tool for cables. The resulting computer-aided design program is named CableCAD®.

The CableCAD® code consists of 3 modules: a finite layer solver; a new finite element solver; and graphical pre- and post-processors. The CableCAD® program was written for personal computers that use either the Microsoft Windows 95 or Windows NT operating systems. The CableCAD® preprocessor was written to simplify creation of finite element cable models. The principal feature of the preprocessor is an interactive graphical database that provides libraries of wire geometries and user-defined components. The graphical environment accelerates the modeling process and improves the accuracy of results. The CableCAD® post-processor produces plots of cable reactions and deformations that provide insight into cable performance and indicate potential design improvements.

Eighteen verification problems were solved with the CableCAD® program, and the CableCAD® predictions agreed well with results presented in the reference literature. The CableCAD® software is expected to advance cable design and manufacturing and prove especially useful in assessing cable performance during handling operations.

As a result of this project, finite element analysis for cable design is commercially available to the defense, scientific and commercial oceanographic cable communities. The CableCAD® software is being produced and sold from Hawaii. Structural Solutions estimates that several hundred cable and rope manufacturers and users will have immediate interest in the CableCAD® software product that was released on the market in Spring, 1999.

KnappEngineering, Inc. dba Structural Solutions, Inc. Aiea, Hawaii. *Low-Cost Prebuckled Cylindrical Pressure Hulls*

The FY94 effort built upon results of FY93 programs to further evaluate the commercial potential of polyhedrally-stiffened (prebuckled) cylindrical (PC) pressure hulls. The technical program from Knapp Engineering, Inc. (KEI) emphasized further development of the low-cost PC hull concept including detailed design, material selection, construction, and testing directly related to manufacturing and potential commercial applications. The goal of the project was to produce PC hulls that operate at 1500 foot depths and cost under $2500 each.

The result is the PC Hull™, a polyhedrally-stiffened cylindrical pressure hull. The PC Hull™ provides several advantages over traditional ring-stiffened smooth cylinders like a lower manufacturing cost, and a high buckling strength with a depth rating 2.5 times or greater than an equivalent smooth hull.

Knapp Engineering, Inc. applied computerized finite element analysis to determine the best shape for the PC Hull™. The optimal geometry depends on the properties of the composite material chosen for manufacturing. After extensive materials testing and considering both performance and cost, E-glass/epoxy was chosen. The finite element analyses selected a polyhedral geometry with an isosceles triangular facet. The shell surface is composed of six circumferential and six axial triangular facets. The designs were optimized to use the least

amount of material for a hull to withstand the pressure at the design depth. The computerized studies predicted that a 0.5 inch thick polyhedral shell wall of E-glass/epoxy would withstand the hydrostatic pressure at a water depth of 1700 feet. The design effort focused on a generic AUV application with measurements of 21 inches diameter and 40 inches long.

Next, various manufacturing methods were studied for effectiveness and cost. KEI chose a filament winding process around an inner mandrel with a clamshell outer mold. Although structural imperfections occurred during prototype manufacturing, since the manufacturing process itself was also a prototype, all prototypes surpassed the computerized predictions. The prototypes were tested at Southwest Research Institute in San Antonio, Texas. When compared to an equivalent smooth hull, the prototype PC Hull™ operated at 2.5 times or greater depths.

Oceanit Laboratories, Inc. (Oceanit) conducted tow tank tests on a prototype to measure hydrodynamic properties of the PC Hull. The data compared well to computerized predictions run by KEI. Although the results show a 60% increase in axial drag over a comparable smooth cylinder, an external smooth fairing could be added to reduce drag.

In addition to increased pressure strength, several factors make the PC Hull™ less expensive to manufacture. Whereas the smooth cylinder must be formed accurately into a circular arc, the PC Hull™ can be formed by less critical molding techniques. Also, because the PC Hull™ is an inherently stiffened cylinder, the stiffening rings used in smooth cylindrical hulls are unnecessary.

The patented PC Hull™ has many uses. Defense applications include autonomous underwater vehicles (AUVs), torpedoes, antisubmarine warfare (ASW) target trainers, and sonobouys. Commercial applications include pressure housings for AUVs, remotely operated vehicles, submersibles, and ocean instrumentation.

A paper on the PC Hull concept was presented at the International Society of Offshore and Polar Engineering (ISOPE) Conference in Honolulu. U.S. Patent # 5,711,244 patent was awarded in January 1998, and KEI established the PC Hull trademark name through use. No commercial sales have resulted to date.

Located in Aiea, Hawaii, Knapp Engineering, Inc. is now called Structural Solutions, Inc..

Makai Ocean Engineering, Inc. Kailua, Hawaii. *Development of a Cost-Effective GPS-Based Sensor for Measurement of Heave, Pitch, Roll and Heading on Oceanographic Platforms (Phase II)*

The project developed and tested a sensor that measures roll, pitch and heading of a platform using short baseline interferometric processing of signals collected from a compact array of GPS receivers. The sensor is intended for use in oceanographic applications where precise measurements of platform rotation are required *e.g.* survey vessels or directional wave buoys. Market analysis indicated a wide potential for commercial applications on ships.

Makai Ocean Engineering, Inc. (MOE) produced a GPS attitude sensor based on results from their CEROS FY93 Core project. The rugged, reliable prototype achieved an accuracy of 0.3 degree rms. for the three attitude rotations using low-cost GPS receivers. To attain 0.3 degree resolution of roll and pitch, MOE used a 3 antenna with 2 meter spacing. A model was developed to predict the performance of various 3 antenna configurations. MOE demonstrated the prototype system on the *R.V. Moana Wave*, an oceanographic research vessel operated by the University of Hawaii. The ship was at sea about half of the three month test period.

Software upgrades produced a sensor capable of tracking up to eight GPS satellites yet able to produce accurate results from as few as three. The sensor accepts a variety of antenna configurations and can work with either a gyrocompass or fluxgate compass to further reduce false solutions. Interface improvements make the system "user friendly."

MOE and the University of Hawaii Department of Ocean Engineering used results from this project to apply for and receive a FY96 Department of Defense (Army) Small Business Technology Transfer (STTR) award entitled "Development of a GPS Directional Wave Buoy". The resulting instrument produced significantly improved directional wave spectral data. The Army invited MOE to submit a proposal for a Phase II upgrade.

Makai Ocean Engineering, Inc. Kailua, Hawaii. *Design, Construction, and Operation of a 50 kW Closed Cycle OTEC Plant and Application of Results to the Design of a One Megawatt OTEC Plant*

This project was competed under the ARPA Mobile Offshore Bases BAA and the award was assigned to CEROS for management. The two-phase project sought to further the development of Ocean Thermal Energy Conversion (OTEC) technology. Phase I involved advanced R&D of the design, construction and operation of a 50 kW closed-cycle (CC) OTEC plant at the Natural Energy Laboratory of Hawaii Authority facility. For Phase II, Makai Ocean Engineering would produce the conceptual design of a one megawatt CC-OTEC plant using the design and operational experience of the 50 kW plant. MOE completed design of the 50 kW CC-OTEC plant and worked with PICHTR and NELHA to construct the plant.

Heat exchanger failure occurred in July 96 because of corrosive pitting to aluminum surfaces. MOE took an aggressive analytic approach to identify the specific causes of failure. The heat exchanger modules were returned to the manufacturer for further analysis, refurbishment, and repair. MOE investigations indicated that compounds released from the nitrile spacer pads in the heat exchangers may be significant factors in the corrosive failures. MOE worked with NELHA to maximize return from investment in CC-OTEC technology. Final report for the Phase I part of the project submitted in November 1996.

MOE delivered a report on the Design Basis and Rationale for a One MegaWatt Closed Cycle OTEC Plant in February 97. This report defines major plant subsystems in a preliminary plant design and is the first deliverable of the second phase of the CEROS-contracted effort. Important design constraints and assumptions are discussed for each subsystem and for the entire, integrated plant.

MOE developed a plan to reconfigure and operate the 50 kW CC-OTEC plant at NELHA using refurbished condenser modules and submitted the plan to the CEROS Research Advisory Board in March 97. This "rescue plan" included single module tests to meet original CEROS and (D)ARPA project goals. The RAB endorsed the proposal and the NELHA Board of Directors authorized up to $200k in additional funding to support the effort. For a time, MOE suspended design and procurement actions for proposed plant modifications pending resolution of the panel refurbishment issues. Replacement heat exchanger panels were delivered to NELHA in October 1998 and PICHTR began reassembling the plant in spring 1999. As of the date of MOE's interim final report, MOE expected to gain access to the plant for its final tasks later in 1999.

Makai Ocean Engineering, Inc. Kailua, Hawaii. *Development of an Automated Control System for Deployment of Small Diameter Cables and Towed Bodies; Loop Avoidance Control for Submarine Cables*

Led by Makai Ocean Engineering, a new generation of cable control software has come on the market. This software is able to account for the integrated time history of the cable lay and to calculate things like bottom tension, slack, and the shape of the cable in the water column, especially near the bottom. The system controls vessel course and speed, cable pay-out rate, solves the linear relationship, and forecasts what action is necessary to achieve desired cable placement. One focus is to minimize errors in "cable touchdown", *i.e.* variations in the actual versus preplanned positions. The mathematical model behind this software is based on the "caternary" solution, or zero stiffness model, where the only force in the cable is tension which (by definition) acts along the axis of the cable. Prior to this project this software did not account for twist and torque developed prior to and during the lay.

The results from this project suggest that a reasonably accurate prediction of cable loop formation under specific lay conditions can be provided. Furthermore the inclusion of stiffness into the cable model opens up a new area of market in the pipeline deployment field. Relatively

simple measurements on cable can provide parameters that will allow prediction of cable loop formation to a reasonable degree of accuracy.

The final product is being marketed to DoD and commercial customers. When MOE sold and delivered a Cable Lay Simulator to Nippon Telephone & Telegraph in 1996, the software modifications to make the simulator more "user friendly" for NTT were applied to the CEROS effort.

Mission Research Corporation. Torrance, California. *Ocean Doppler Lidar*

In preliminary trials at a University of Hawaii facility, Mission Research Corporation demonstrated a new way to detect underwater moving objects at long range in shallow waters. For the first time, underwater moving targets were detected with a laser radar (lidar) using their Doppler signature. MRC developed a novel Moving Target Indicator (MTI) filter that rejects ocean optical clutter so Doppler processing can be used to reject backscattered energy while passing the light scattered from moving objects.

Mission Research Corporation demonstrated the Ocean Doppler Lidar at the J.K.K. Look Laboratory Optical Test Range operated by the University of Hawaii at Kakaako Penisula, Oahu. Researchers observed unmistakable lidar signatures from an underwater moving belt target at 300 m range and 5 m depth. This initial detection of an underwater moving object with a laser achieved over 15 dB target-to-clutter ratio at shallow grazing angles. Previous tests at NRaD in 1978 achieved a 0.8 dB ratio. The results demonstrate that the Doppler filter is capable of rejecting clutter and passing the target signal, in ocean field conditions, thereby confirming the utility of the Ocean Doppler Lidar.

If verified, proven, and developed to a systems level, the Ocean Doppler Lidar concept could provide a means of long-range shipboard detection of underwater moving objects, such as torpedoes or, possibly, submarines.

Neptune Technologies, Inc. Kailua, Hawaii. *Diver Homing Device*

Neptune Technologies, Inc. designed, built, and field tested a prototype electro-acoustic system that allows a diver to home on an ultra-sonic transmitter. To improve directional sensitivity, the device is designed to use the diver's body and equipment as an acoustic shield.

The receiver and transmitter are compatible with other diver-carried accessories. An indicator light on the receiver illuminates only when the diver is aligned with the transmitter. The transmitter is small enough to be moved by a diver. The Diver Homing Device has an effective range of at least 20 times dive depth for depths not exceeding 25 meters; the maximum design range is 500 meters. Both transmit and receive units are powered by self-contained batteries with a minimum lifetime of 10 hours per unit.

A particular feature of the Diver Homing Device is the design that uses the diver's body and equipment as an acoustic shield to increase directionality. Neptune Technologies noted, however, that multipath reflections and reverberation from the sea surface or bottom may reduce directionality for some sea or bottom conditions. Several simple techniques were tried to adjust transmitter output to minimize reverberation and maximize directionality for various environmental conditions. Overall, the device proved efficient for a wide range of environments and conditions.

The Diver Homing Device met or exceeded all performance requirements and contract specifications. Neptune Technologies is preparing to test the device further in "real world" situations, with an eye toward commercialization and production of a final product. Neptune Technologies received a United States patent for technologies related to this CEROS-sponsored demonstration project.

Ocean Engineering Consultants, Inc. Honolulu, Hawaii. *SWATH Motion/Structural Software Development*

Ocean Engineering Consultants, Inc. created and/or adapted engineering design software code to design and test Small Waterplane Area Twin Hull (Swath) ships. With funding in CEROS FY94, FY95, and FY96, OEC sought to develop and validate a software tool to calculate and visualize flow patterns around and in the vicinity of a Swath-type hull. OEC conducted an integrated software development to create a "numerical tow tank" for Swath and multi-hull vessels, to extend software capabilities, test and verify the software, and to provide a preliminary guide for finite element model. The software package has three analytic options: quasi-static, hydro-elastic, and rigid-dynamic. It is particularly useful for critical placement and flow alignment of hull appendages, and for analyzing Swath vessels in special situations, such as close running with another vessel or oceanographic instrument deployment. This sophisticated software decreases the time and cost necessary to design faster, more stable ships for the military and civilian markets. Ocean Engineering Consultants, Inc. markets its engineering design services worldwide and features Swath ship designs with its advanced software tools.

ORINCON, Hawaii, Inc. Kailua, Hawaii. *Underwater Echolocation for Buried Objects*

This three-year effort by ORINCON Corporation and the Hawaii Institute of Marine Biology (HIMB) of the University of Hawaii focused on attaining "dolphin-like" echolocation performance to detect and classify buried objects in cluttered environments using a prototype, real-time, automated broadband active sonar system. The ORINCON team defined dolphin echolocation performance criteria, developed the biomimetic signal and information processing system to match that performance, and demonstrated the system integrated on a bottom-crawling remotely operated vehicle (ROV). The real-time signal processing was performed with proprietary ORINCON software and commercial off-the-shelf (COTS) hardware provided to HIMB by the Office of Naval Research.

During this effort, ORINCON also implemented a signal processing model based on the dolphin cochlear system and quantified the model's performance. Overall, ORINCON demonstrated (1) that their biomimetic signal and information processing system could -- in real-time -- effectively represent, detect, and classify underwater echolocation returns from objects located on the bottom or buried in the sediment; (2) that a multifeature fusion classification system can achieve a level of performance greater than that of an individual feature-based system; and (3) that models, such as those based on wavelet transform and the dolphin cochlea, show particularly promising signal representation capabilities.

ORINCON Hawaii, Inc. Kailua, Hawaii. *Advanced Real-Time Signal Processor*

ORINCON Hawaii, Inc. provided automated mission support tools to improve the tactical sonar system capabilities available to the Commander Submarine Forces Pacific (COMSUBPAC). Additional functional capabilities, requested by COMSUBPAC, were developed and integrated into the ARTS processor. The ARTS processor is a compact, powerful, real-time signal and information processing system that was developed by ORINCON Hawaii, Inc. using commercial, off-the-shelf (COTS) hardware. Interfaced to submarine sensor systems, ARTS provides full azimuth, real-time display and alert of passive acoustic signals for U.S. Navy submarines. Sea tests on a Pacific Fleet submarine resulted in very positive feedback. Follow-on funding in later years transitioned the product from water to the air for the Maritime Patrol Aircraft.

ORINCON, Hawaii, Inc. Kailua, Hawaii. *Submarine-Launched, Two-Way, Fiber Optics Linked Communications Buoy*

This project addressed a generalized Navy need to provide capabilities to enable undersea platforms to communicate with war fighting commanders and Navy surface and air elements while remaining at operating depths. The need is for wide-band, two way communications between the submarine and surface or air elements. In this CEROS-supported effort, Orincon Hawaii and their subcontractor Sippican Corporation sought to demonstrate the feasibility of providing an optical fiber link to enable communications between a submarine operating at depth and an antenna buoy at the ocean surface. The effort included a feasibility study of optical fiber links, a spectral trade-off analysis to maximize performance, and a packaging study to show that the subsystem required could fit within the submarine signal ejector volume. The principal focus of the effort was to modify an AN/BRT-6 transmit antenna and demonstrate its radio frequency functionality. The antenna's functionality was demonstrated in June 97. The results of this effort point the way to a follow-on project to address critical submarine data processing and communication system requirements. Such a project was funded in the CEROS FY97 Core program.

Pacific Marine & Supply Co. Honolulu, Hawaii. *Tri-strut Ship Research, Development and Test Model: MidFoil*

Pacific Marine & Supply Co. combined funds from CEROS, the Hawaii Electric Vehicle Development Program, and MARITECH of DARPA to design, test, and build a manned model of a new ship design called "MidFoil." Rather than a traditional v-hull or even a catamaran-style SWATH, the MidFoil has a foil-shaped body placed amidships to provide displacement. CEROS supported the computerized design and testing with computational fluid dynamics, small-scale physical model tests, and construction of the unique foil for the 65-foot manned model. The 50 ton vessel was launched in Honolulu Harbor in January 1998 and ran successfully. The vessel exhibits an extremely smooth, stable ride even in rough seas and at speeds over 20 knots. The design can be scaled up to 10,000 tons for various DoD applications and commercial applications like shipping and ferries. Results have direct application to ARPA and ONR advanced fast ship programs. Benefits from the Tri-Strut effort were applied to the Pacific Marine SLICE program.

Sea Engineering, Inc. Waimanalo, Hawaii. *Development of a Technique to Identify Pollutant Sources and Impacts in Coastal and Oceanic Waters*

Sea Engineering, Inc. with subcontractors from CalTech studied whether Inductively Coupled Plasma Mass Spectrometry (ICP-MS) could be used to measure freshwater discharges into saline coastal waters in Hawaii. Although previous work had applied ICP-MS to fresh and slightly saline waters, this was the first trial of the technique on samples from fully saline or oceanic waters. The ICP-MS technique is capable of identifying elements and suites of elements in discharge sources. However the unique spectral "fingerprints" that have been identified for mainland streams and rivers were not found in stream samples from O'ahu. Furthermore, the low concentrations of elements in the O'ahu discharges were masked by high concentration of "salt" ions in saline samples. Differences in rare earth elements between freshwater and saline samples provided a "reverse tracer" that enabled Sea Engineering to develop an accurate measure of dilution to trace effluent discharge plumes in the ocean. The project provided important fundamental data for applying the powerful ICP-MS technique to oceanic environments.

Sea Engineering, Inc. Waimanalo, Hawaii. *Development of a Broad-band FM Sub-bottom Profiler for Seafloor Imaging and Sediment Classification*

This work demonstrated the function and utility of the broadband FM sub-bottom profiler developed with FY93 CEROS support. Sea Engineering developed and tested a state-of-the-art broadband, sub-bottom acoustic profiling system for shallow water surveys. The system provides rapid and accurate bottom classification and characterization. It is uniquely capable of distinguishing consolidated and unconsolidated coral sands, as demonstrated during field tests off Waikiki Beach. The contractors developed expert system classification rules and interactive interface for the subbottom profiler system. The classification algorithms were upgraded using fuzzy logic rules. The profiler was delivered from Florida, assembled and tested in four diverse areas; sand deposits not previously imaged were identified. This development extends technology applied at NUSC and for NRL Benthic Boundary Layer program. Sea Engineering seems to be developing a "breakthrough" technological tool for commercial application in the Pacific. In May 1996, the Geological Survey of the United States Department of the Interior contracted with Sea Engineering to survey sediment deposits in Kailua Bay, O'ahu using the profiler. The survey's chief scientist acknowledged the Sea Engineering system as providing excellent records to support deposit volume, composition, and history estimates.

Science & Technology International, Inc. formerly SETS Technology. Honolulu, Hawaii. *Hyperspectral Remote Sensing (AAHIS) for Maritime Applications: Phase II*

In this project, SETS Technology, now known as Science & Technology International (STI), developed the first hyperspectral sensor system with the required signal-to-noise ratio (SNR) and spatial and spectral resolution adequate for advanced maritime applications. During the first phase of the project, a flight-tested, visible/near-infrared (430 to 840 nm) hyperspectral imaging system, was optimized for use in maritime applications—advanced airborne hyperspectral imaging system (AAHIS). The AAHIS system offers the ability to do high-speed, wide-area surveillance from an airborne platform.

Under CEROS FY93, STI adapted its proprietary signal-processing scheme into a prototype airborne hyperspectral imaging system for near-shore surveillance and mapping, adapted advanced sensor system into marine applications. The FY94 effort focused on improving the resolution of the advanced airborne hyperspectral imaging system (AAHIS), and demonstrated the system's capabilities. STI increased the search rate, resolution, and accuracy of the AAHIS system and demonstrated specific applications. STI increased spatial resolution five-fold, incorporated image stabilization into the AAHIS flyaway package, provided on-board real-time spectral image processing, and integrated differential GPS with a geographic information system.

The AAHIS flight navigation system was completed, and high resolution AAHIS data were collected from Kaneohe Bay. A mirror stabilization system for AAHIS was developed by SETS to meet project schedules and deadlines. SETS has "captured" a technology from SAIC and developed it within a specific maritime, littoral niche. DoD demonstration of AAHIS technology application being coordinated through the Navy Technology Insertion Program (NTIP). Based on the work sponsored by CEROS, STI has secured over $10 million in funding from other federal sources to continue development of AAHIS-related projects.

Science & Technology International, Inc. formerly SETS Technology. Honolulu, Hawaii. *Grazing Angle Imaging Lidar (GAIL) for Organic Mine Countermeasure*

SETS Technology, Inc., now known as Science & Technology International (STI) developed and demonstrated a prototype "grazing angle" (4 to 6 degrees below horizontal) imaging LIDAR system for detecting and discriminating objects in shallow water. This prototype mine countermeasure system is based on the LIDAR return of pulsed LASER light at near incident grazing angles to the sea surface.

As part of the CEROS-sponsored effort, STI performed a mission analysis and concept definition study for grazing angle LIDAR systems. STI contends that a system such as GAIL could function as an "organic" (that is, own ship) mine countermeasure system for escort ships in a battle group, on landing craft, or as part of a point defense system ashore or afloat.

In addition to the system concept definition study STI assembled a "breadboard" system, tested the system at NELHA, and developed a top-level system description for an operational GAIL MCM system. The resulting system model identifies the landing craft mounted system as the leading candidate for a "real world" GAIL application.

During tests at NELHA, the breadboard GAIL system demonstrated single pulse detection of mine-like targets in clear ocean water to depths of 65 feet. STI reports that greater detection depths would be possible with more elaborate real-time signal processing for the signals. For the tests, the prototype system used a frequency-doubled flashlamp pumped Nd:YAG laser from Big Sky Laser with maximum output energy at 532 nm wavelength of 125 microjoules per pulse. The laser operated at a pulse repetition frequency between 10 and 30 Hz. STI developed and installed a unique "haul down" mooring system to test the GAIL prototype at NELHA. STI conducted the proof-of-concept testing at NELHA efficiently and in full compliance with FAA, Coast Guard, and environmental regulations.

The STI effort showed that the GAIL system concept is practical and that the preliminary system model is valid. Results are sufficient to support development of a prototype sensor system. However, STI also recommends further testing to refine the system concept for operational utility.

Science & Technology International, Inc. formerly SETS Technologies. Honolulu, HI. *Dual Mode Fluorescence Imaging for Maritime Applications*

SETS Technology, now known as Science & Technology International (STI), proposed to develop and demonstrate a dual mode, multi-spectral fluorescence imaging system (DFI) for through-the-surface and subsurface maritime applications. The DFI system would be the first to use both ultraviolet and visible wavelengths in a dual mode (reflectance and fluorescence) imaging system. The goal of the DFT/SHI is to provide quantitative, nondestructive remote discrimination and characterization of marine and littoral zone phenomena. Targeted missions include assessing coral reef health, mapping and dectecting benthic pollutants, tracking contaminant streams, mapping plankton, mapping fish, and mine and unexploded ordinance detection/discrimination. The phase I work included: (1) design and assemble the DFI system; (2) collect through-the-surface and subsurface multispectral reflectance and fluorescence data from a variety of targets; (3) develop spectral discrimination algorithms; (4) develop spectral detection and characterization algorithms; and (5) validate the DFI model in Pearl Harbor and Kaneohe Bay. STI configured the DFI system to perform both laser-generated DFI and passive hyperspectral imaging from the same "pushbroom" configuration. A supplemental agreement extended the effort to provide for demonstration of system in coral reef assessment project, and an additional $100k was provided by CEROS to support demonstration (total project funding = $895k).

The phase II work plan included several system upgrades, and the integration and field-testing of the system on a helicopter. During the contract, the aircraft was changed from a helicopter to a Piper Navajo small airplane but the field testing of the full system was blocked by lack of FAA approval for the instrument housing. Ground-based tests of the active, fluorescence device were conducted at Barber's Point Naval Air Station. The passive, hyperspectral device was flown over Pearl Harbor on a Panavia aircraft. The active data was somewhat inconclusive, and the passive data was successful.

Synthetic Technologies, Inc. Honolulu, Hawaii. *Bioactive Marine Isonitrile Compounds from Hawaiian Sponges as Models for Synthetic Nontoxic Antifoulant and Antibiotic Agents*

This exploratory work is based upon (1) the observations that some sessile marine organisms remain significantly free of biologically based fouling and (2) the speculation that such organisms possess chemical defenses against fouling organisms.

Synthetic Technology Corporation developed and tested synthetic isonitrile compounds based on the natural metabolite *isocyanopupukeanane*, isolated from the marine sponge *Ciocalypta* sp., for effective, nontoxic, antifouling activity against common ship fouling organisms typical of the Pearl Harbor marine community. These and closely related compounds were also be tested as antibiotics, particularly as inhibitors of microbial biofilm, which is suspected to play role in in biologically signaling suitability for settlement of larvae of significant marine invertebrate fouling organisms. The active compounds were incorporated using several techniques into marine paint and field tested in the ocean for antifouling activity using *Hydrodies elegans* (a calcareous tube worm) as a representative ecological receptor.

Synthetic Technology Corporation has demonstrated that several naturally occurring compounds have potentially significant antifouling properties. However, most successful results are from laboratory bioassay studies and the compounds' antifouling potential has yet to be reproduced in ocean trials of paint formulations. The challenge remains to carry the compounds' antifouling capability into a practical formulation which efficiently delivers the active ingredient to the host organisms over an extended period of time.

TerraSystems, Inc. Honolulu, Hawaii. *Development of an Underwater Video Camera for Optical Contrast and Range Enhancement Using Spectral Stretching*

The objective of this project was to develop a working prototype of an underwater video camera with enhanced optical contrast, enhanced range performance, and real-time color video display for the diver (and surface monitor) using a technique termed "Spectral Stretching." A prototype was developed (the UCSS: Underwater Camera Using Spectral Stretching) and tested in a variety of underwater environments: shallow, deep (70 feet), clear, and turbid.

Research into the radiative transfer properties show that improved visibility and contrast to the human eye is possible if the nearly monochromatic (green) light at depth is split into narrow bands and re-imaged on a video screen as red, green and blue. A specially designed liquid crystal tunable filter (LCTF) and image intensified camera were enclosed in a watertight submersible housing and driven by computer control at video rates. The sequential images taken through each filter state of LCTF (at 30 Hz) were recombined as RGB for display.

Tests in shallow turbid water off Waimanalo show increased contrast performance relative to the eye and video camera. Tests in deep water off Hawai'i Kai show increased color contrast (compositional discrimination) over the eye, video camera, and color film.

The UCSS approach has potential applications in all underwater activities where optical range and contrast enhancement is important. The applications for the DoD and the private sector include environmental monitoring (e.g. coral reef species discrimination and health), inspection of underwater pipelines, communication lines, oil and gas well heads, pilings, moorings and piles, and surveys for unexploded ordnance or mines.

Recommendations for follow-on work include additional testing in more diverse environments, the development of an underwater computer (module) for miniaturization, the testing of different camera systems such as large dynamic range intensified CCD systems, and higher throughput LCTF. The spectral imaging techniques developed here can be applied to other underwater mapping and optical systems.

Thermal Energy Storage, Inc. San Diego, California. *Development and Testing of a Clathrate Desalination Research Facility*

Desalination is the process of producing potable water from seawater. The clathrate desalination plant is based on two fundamental principles: (1) when seawater freezes, salt is excluded from the ice crystal so freshwater may be obtained from the ice, and (2) clathrates are a class of chemicals that can crystallize or "freeze" water at temperatures well above the normal water freezing point. This project sought to design, build, operate and test a high pressure crystallization facility and a water purification and clathrate recovery system at the Natural Energy Laboratory of Hawaii Authority (NELHA) as an adjunct to an existing desalination pilot plant. Preliminary research by Thermal Energy Storage, Inc. (TESI) indicated that fresh water by clathrate desalination can be produced at a cost of $0.53/m^3 ($2.00/1000 gal.).

Makai Ocean Engineering, Inc. designed and constructed the high-pressure clathrate/water crystallizer at NELHA. The clathrate forming chemical is HCFC R141b (dichloromonofluoroethane (CCL_2FCH_3). The crystallizer houses the seawater phase change and separation to freshwater ice and excluded salt slurry. Makai learned that water from the 3000' depth at NELHA provided a sufficiently low temperature for natural clathrate formation. Tests showed that clathrates were formed spontaneously, and that the high pressure had little affect on the freezing temperature.

Thermal Energy Storage, Inc. designed and assembled the water purification- clathrate recovery system and integrated it with the pilot plant. TESI operated the Clathrate Desalination Pilot Plant intermittently over a period of several months. The system did not perform to design specifications and relatively small quantities of clathrate ice were produced. The water produced had a salinity of about 500 ppm total dissolved solids, the EPA's potability limit. The results validated the concept of a clathrate desalination plant.

All of the elements of the plant functioned as intended except for one subsystem, the wash column, which was to collect and wash brine from the surface of the clathrate crystals. Engineering and testing work done since completion of the CEROS funded work indicates that the drain area of the wash column must be increased substantially to make the system operational.

Varian Medical Systems, Inc. Mountain View, California. *Laser Heterodyne Imaging For Shallow Water Surveillance*

Varian Associates, Inc. developed a proof-of-concept imaging system for object identification in very turbid waters (visibility range 50-80 cm). The Varian system obtained images with millimeter resolution at a range of over 10 attenuation lengths. The Varian prototype system exceeded the range and resolution capabilities of all existing optical systems for imaging in highly turbid waters.

To achieve the technological breakthrough demonstrated with the prototype laser imaging system, Varian used long wavelength (683nm) illumination, coherence gating, and heterodyne detection. The resulting system produced exceptional resolution and images in highly turbid waters during laboratory tests and demonstrations. The tests were run on a specially built underwater optical bench at the Varian facility in specially mixed water that duplicated the optical properties of highly turbid seawater in the littoral zone.

Under CEROS sponsorship, Varian created a novel laser heterodyne system and achieved unprecedented image resolution in very turbid seawater. Under CEROS FY97, Varian improved the unique heterodyne imaging system for object detection in littoral waters.

DARPA GRANT NO. MDA 972-94-1-0010
FINAL TECHNICAL REPORT

CONTENTS

1.0 INTRODUCTION

As the *Ocean State*, Hawaii has been a leader in ocean-directed research for many years. In the late 1960's, for instance, the study, *Hawaii and the Sea*, highlighted research areas to be pursued by government, academic, or commercial organizations. Hawaii's mid-Pacific location is unique and allows extraordinary access to a variety of ocean environments–particularly the deep ocean–in a climate generally mild enough for year-round, at-sea activity.

Department of Defense (DoD) ocean-related activities, facilities, and assets in Hawaii are also numerous, exceptional, and long standing. Recent DoD emphasis has focused on providing advanced technology to both war-fighting and support units, while emerging DoD programs seek to increase use of commercially developed advanced within DoD systems and system-development cycles. Hawaii provides an ideal location for a federally supported state program to develop ocean technologies for DoD applications.

1.1 CONGRESSIONAL ACTION

The National Defense Center of Excellence for Research in Ocean Sciences (CEROS) was created by congressional action. House Bill 8761, published in the September 18, 1992, *Congressional Record*, contained a section entitled *Research, Development, Test, and Evaluation, Defense Agencies* and provided for

> "...an additional amount for RESEARCH, DEVELOPMENT, TEST AND EVALUATION, DEFENSE AGENCIES, $74,800,000, to remain available for obligation until September 30, 1993. Provided that $5,000,000 of the funds appropriated in this paragraph shall be made available only for a National Defense Center of Excellence for Research in Ocean Sciences to be established through cooperation between the Defense Advanced Research Projects Agency (DARPA) and the Hawaii High Technology Development Corporation (a government entity) for the purpose of conducting research and development (R&D) activities of interest to the Department of Defense on such topics as ocean environment preservation technology, new ship hull design concepts, shallow water and surveillance technologies, ocean measurement instrumentation, and the unique properties of the deep ocean environment."

1.2 NATIONAL DEFENSE CENTER OF EXCELLENCE FOR RESEARCH IN OCEAN SCIENCES (CEROS)

1.2.1 Background

In February 1993, DoD technical needs–combined with ocean technology capability in Hawaii–yielded the National Defense Center of Excellence for Research in Ocean Sciences (CEROS). CEROS was established through a grant from the Defense Advanced Research Projects Agency (DARPA) to the High Technology Development Corporation (HTDC), an agency of the State of Hawaii attached to the Department of Business, Economic Development and Tourism (DEBDT). CEROS was funded

> ". . . for the purpose of conducting research and development activities of interest to the Department of Defense . . . and . . . to support and stimulate a broad spectrum of research in ocean science in the State of Hawaii."

1.2.2 DARPA Grant No. MDA 972-93-1-0008

DARPA awarded Grant No. MDA 972-93-1-0008 for $5,000,000 to HTDC for CEROS in February 1993. This grant supported a core program of eleven projects involving twelve prime contractors during the CEROS FY93. Technical work was complete for this grant by December 1997, and the final grant report was delivered to DARPA in September 1998.

1.2.3 DARPA Grant No. MDA 972-94-1-0010

DARPA awarded MDA 972-94-1-0010 for $5,000,000 to HTDC for CEROS in May 1994. A copy of the grant is attached as Appendix A. This grant supported a core program of thirty-nine projects involving nineteen prime contractors during CEROS FY94, FY95, and FY96; contract details are listed in Tables 1.1, 1.2, and 1.3, respectively. All contracts were complete by the end of June 1999. This report describes the work done under the 1994 grant.

The purpose of the grant is

> ". . . to support and stimulate a broad spectrum of research in ocean science in the State of Hawaii. This effort shall be carried out generally as set forth in the Grantee's proposal entitled 'Operational Plan, National Defense Center of Excellence For Research In Ocean Sciences (CEROS)'. . ."

1.2.4 State Oversight and Interaction

Total funding to CEROS for Grant No. MDA 972-94-1-0010 was $18,738,XXX. The State of Hawaii and DBEDT recognize that building and reinforcing a competitive ocean R&D community–with guided networking, marketing, and new business interchanges–is an important function of CEROS. Originally, Grant No. MDA 972-94-1-0010 for CEROS was administered by the State of Hawaii through HTDC. In December 1995, the DARPA grants that funded

CEROS were transferred from HTDC to the Natural Energy Laboratory of Hawaii Authority (NELHA), another State of Hawaii agency.

1.2.5 Program Summary

CEROS advances the state's goals of expanding technology-based industries by encouraging the participation of Hawaii companies that have special expertise of interest to DoD. The HTDC (and, later the NELHA) Board of Directors set broad goals, developed policy, and provided guidance for the general management and direction of CEROS under Grant No. MDA 972-94-1-0010. As CEROS grantor, DARPA reviewed and evaluated CEROS programs and management to assure grant conformance and consistency with congressional intent.

The CEROS Technical Director is the grant's Principal investigator and is responsible for technical program development and execution. The Technical Director impanels a research advisory board to provide functional oversight, guidance, and advice throughout the CEROS source-selection process and to plan and implement strategic development. As a condition of funding, CEROS programmatic goals and managerial approaches are presented to DARPA annually as an operational plan.

1.2.6 Program Objectives

The CEROS mission is to:

- Support the Department of Defense,
- Encourage leading-edge R&D in ocean sciences,
- Use Hawaii's exceptional ocean research facilities,
- Involve recognized highly specialized small businesses in ocean research, and
- Develop access to ocean science expertise and facilities at the University of Hawaii.

The CEROS technical program seeks to identify leading-edge, value-added technologies that support DoD requirements, use facilities and infrastructure in Hawaii, and foster potential commercial development. The technical topic areas addressed by the CEROS program were identified in the congressional legislation as:

- Ocean environmental preservation technology
- New ocean platform and ship concepts
- Shallow water surveillance technologies
- Ocean measurement instrumentation
- Unique properties of the deep ocean environment.

1.2.7 Program Scope

CEROS supports R&D projects that are intended to produce measurable results of products within 12 months. Procurement is based on priorities that are issued in published

solicitations, emphasizing near-term results. Because out-year funds are not assured, program announcements require proposals to be structured accordingly. Proposals can include options for appropriate funding continuations or transitions beyond the desired 12-month performance period. However, funds for such options are not automatic but will be considered separately according to source-selection procedures and fund availability.

If a project is proposed that probably cannot be procured within time or budget limitations, the CEROS Technical Director and research advisory board will try to reduce the risks and consequences of postponing, scaling, or not funding. Trade-offs between cost, performance, and schedule are evaluated relative to programmatic goals and planned procurement schedule and appropriate risk-reduction strategies are identified and implemented.

1.2.8 Procurement

CEROS selects and supports technical projects that conform to its mission. CEROS procures R&D based on programmatic priorities and goals; the resultant procurement contracts include terms and schedules for delivery. Proposals for R&D projects are requested through Broad Agency Announcements (BAAs) from qualified companies or consortia that can employ consultants and share facilities to fully support the objectives of the proposed effort. The selection process emphasizes technology development in Hawaii and the Pacific without eliminating applicable projects of merit with a focus elsewhere. CEROS determines best value through technical and programmatic evaluations that match proposed efforts with DoD technology needs and CEROS programmatic objectives within funding constraints. As a condition of funding, DARPA approves CEROS contract policy and procedures and assures that they are consistent with applicable federal acquisitions regulations and guidelines.

The BAA was published in *Commerce Business Daily* for FY94, FY95, and FY96 on March 8, 1994, December 19, 1994, and December 21, 1995, respectively. Copies of the BAA for each year are attached as Appendix C. The Program Review schedules are attached as Appendix D.

DARPA GRANT NO. MDA 972-94-1-0010
FINAL TECHNICAL REPORT

TABLE 1-1
CEROS 1994 PROJECTS

Contractor	Project	Amount	Contract No.
Alliant Techsystems Inc.	High-Resolution Bottom-Penetrating Acoustic Sensors and Signal Processing Algorithms for Reduction of False-Alarm Probability in UXO Hunting	$980,766	38107
Aquaculture Technology Inc.	Naturally Occurring Antibodies from Marine Algae Chaetoceros	$171,485	38080
Detection Limit Technology, Inc.	Development of a Fiber-Optic Based Autonomous Buoy for *In-Situ* Monitoring of pH, pCO_2, Temperature, O_2, and Water Quality in Seawater	$331,800	38194
Gateway Technologies International, Inc.	HIRADSIM Workstation Development Project. Continuation of Existing Work Advanced HIRADSIM Small TRGET, Time Domain, Maritime Radar Mode.	$250,000	38108
Innovations Hawaii	Extended-Source Apparent Motion (E-SAM) Lighted Signals for Protection of the Marine Environment	$177,180	38195
Knapp Engineering, Inc.	Low-Cost Prebuckled Cylindrical Pressure Hulls	$571,000	38110
Oceanit Laboratories, Inc.	Low-Cost Prebuckled Cylindrical Pressure Hulls	$91,000	38203
Makai Ocean Engineering, Inc.	Development of a Cost-Effective GPS-Based Sensor for Measurement of Heave, Pitch, Roll and Heading on Oceanographic Platforms (Phase II)	$235,000	38102
Makai Ocean Engineering, Inc.	Design, Construction, and Operation of a 50 kW Closed Cycle OTEC Plant and Application of Results to the Design of a One Megawatt OTEC Plant	$649,759	38985
Makai Ocean Engineering, Inc.	Development of an Automated Control System for Deployment of Small Diameter Cables and Towed Bodies	$325,000	38111
Ocean Engineering, Inc.	SWATH Motion/Structural Software Development	$121,000	38081
ORINCON Corp.	Underwater Echolocation for Object Recognition	$652,685	38082
Pacific Marine & Supply Company, Inc.	Tri-strut Ship Research and Development	$365,400	38242
Sea Engineering, Inc.	Development of a Technique to Identify Pollutant Sources and Impacts in Coastal and Oceanic Waters	$146,000	38103
Sea Engineering, Inc.	Development of a Broad-band FM Sub-bottom Profiler for Seafloor Imaging and Sediment Classification	$223,870	38109
Science and Technology International (STI)	Hyperspectral Remote Sensing (AAHIS) for Maritime Applications: Phase II	$647,974	38101

TABLE 1-2
CEROS 1995 PROJECTS

Contractor	Project	Amount	Contract No.
Alliant Techsystems Inc.	High-Resolution Bottom-Penetrating Synthetic Aperture Sonar Using Multi-Vertical Row Array and Subbottom Classification	$990,083	39570
Aquaculture Technology Inc.	Naturally Occuring Antibacterial and Antifungal Substances from Marine Algae Chaetoceros, Nitzschia, and Thalassiosira	$206,960	39604
Mission Research Corporation	Ocean Doppler Lidar	$381,000	40323
Neptune Technologies, Inc.	Diver Homing Device	$200,000	40295
Ocean Engineering, Inc.	SWATH Motion/Structural Software Development and Verification	$168,000	40464
ORINCON Corp.	Underwater Echolocation for Object Recognition, Phase 3	$696,925	39503
ORINCON Corp.	Advanced Real-Time Multifunctional Signal Processor	$862,095	39571
Pacific Marine & Supply Company, Inc.	Design, Construction and Sea Trials of a 30-Foot Manned Test Model of a Midfoil SWAS	$780,000 $24,000	39797 42787
Science and Technology International (STI)	Dual Mode Fluorescence Imaging for Maritime Applications	$894,976	39496
Synthetic Technology Corporation	Bioactive Marine Isonitrile Compounds from Hawaiian Sponges as Models for Synthetic Nontoxic Antifoulant and Antibiotic Agents	$155,055	39616
Varian Associates, Inc.	Laser Heterodyne Imaging for Shallow Water Surveillance	$299,674	39615

TABLE 1-3
CEROS 1996 PROJECTS

Contractor	Project	Amount	Contract No.
Alliant Techsystems Inc.	High-Resolution Bottom-Penetrating Synthetic Aperture Sonar For Use in Buried UXO Hunting	$982,087	41401
Detection Limit Technology, Inc.	Solution Plus *In-Situ* Ocean Sediment Chemical Analyzer	$320,000	41282
Knapp Engineering, Inc.	Finite Element Design of Cables	$145,000	41490
Makai Ocean Engineering, Inc.	Loop Avoidance Control During the Deployment and Retrieval of Submarine Cables	$287,000	41526
Ocean Engineering, Inc.	Flow Simulation and Visualization for SWATH Ships	$161,372	41366
ORINCON Corp.	Submarine-Launched, Two-Way, Fiber Optics Linked Communications Buoy	$160,000	41941
ORINCON Corp.	Advanced Real-Time Sensor (ARTS) Upgrade	$871,771	41487
Science and Technology International, Inc. (STI)	Grazing Angle Imaging Lidar (GAIL) for Organic Mine Countermeasure	$698,277	41357
Science and Technology International (STI)	Dual Mode Fluorescence Imaging for Maritime Applications: Phase II	$996,428	41365
Synthetic Technology Corporation	Bioactive Marine Isonitrile Compounds from Hawaiian Sponges as Models for Synthetic Nontoxic Antifoulant and Antibiotic Agents II. Synthetic Analogs, Paint Formulations, and Mechanisms of Action	$326,553	41777
TerraSystems, Inc.	Development of an Underwater Video Camera for Optical Contrast and Range Enhancement Using Spectral Stretching	$247,323	41358
Thermal Energy Storage, Inc.	Development and Testing of a Clathrate Desalination Research Facility	$250,000	41367

TABLE 1-4
CUMULATIVE CEROS 1994, 1995 & 1996 PROJECTS

Contractor, Funding Years	**Chp**	**Project**	**Amount**	**Contract No.**
Alliant Techsystems Inc. 94, 95, 96	2	High-Resolution Bottom-Penetrating Acoustic Sensors and Signal Processing Algorithms for Reduction of False-Alarm Probability in UXO Hunting	\$980,766 \$990,083 \$982,087 **\$2,952,936**	38107 39570 41401
Aquaculture Technology Inc. 94, 95	3	Naturally Occurring Antibodies from Marine Algae Chaetoceros-	\$171,485 \$206,960 **\$378,445**	38080 39604
Detection Limit Technology, Inc. 94, 96	4	Development of a Fiber-Optic Based Autonomous Buoy for *In-Situ* Monitoring of pH, pCO_2, Temperature, O_2, and Water Quality in Seawater RENAME???	\$331,800 \$320,000 **\$651,800**	38194 41282
Gateway Technologies International, Inc. 94	5	HIRADSIM Workstation Development Project. Continuation of Existing Work Advanced HIRADSIM Small Target, Time Domain, Maritime Radar Mode.	\$250,000	38108
Innovations Hawaii 94	6	Extended-Source Apparent Motion (E-SAM) Lighted Signals for Protection of the Marine Environment	\$177,180	38195
Knapp Engineering, Inc. 96	7	Finite Element Design of Cables	\$145,000	41490
Knapp Engineering, Inc. 94	8	Low-Cost Prebuckled Cylindrical Pressure Hulls	\$571,000	38110
Oceanit Laboratories, Inc. 94	8	Low-Cost Prebuckled Cylindrical Pressure Hulls	\$91,000	38203
Makai Ocean Engineering, Inc. 94	9	Development of a Cost-Effective GPS-Based Sensor for Measurement of Heave, Pitch, Roll and Heading on Oceanographic Platforms (Phase II)	\$235,000	38102
Makai Ocean Engineering, Inc. 94	10	Design, Construction, and Operation of a 50 kW Closed Cycle OTEC Plant and Application of Results to the Design of a One Megawatt OTEC Plant	\$649,759	38985
Makai Ocean Engineering, Inc. 94, 96	11	Development of an Automated Control System for Deployment of Small Diameter Cables and Towed Bodies; Loop Avoidance Control for Submarine Cables	\$325,000 \$287,000 **\$612,000**	38111 41526
Mission Research Corporation 95	12	Ocean Doppler Lidar	\$381,000	40323
Neptune Technologies, Inc. 95	13	Diver Homing Device	\$200,000	40295
Ocean Engineering, Inc. 94, 95, 96	14	SWATH Motion/Structural Software Development	\$121,000 \$168,000 \$161,372 **\$450,372**	38081 40464 41366
ORINCON Corp. 94, 95	15	Underwater Echolocation for Object Recognition	\$652,685 \$696,926 **\$1,349,611**	38082 39503
ORINCON Corp. 95, 96		Advanced Real-Time Signal Processor	\$862,095 \$871, 771	39571 41487

	16		**$1,733,866**	
ORINCON Corp. 96	17	Submarine-Launched, Two-Way, Fiber Optics Linked Communications Buoy	$160,000	41941
Pacific Marine & Supply Company, Inc. 94, 95	18	Tri-strut Ship Research and Development; MidFoil	$365,400 $780,000 $24,000 **$1,169,400**	38242 39797 42787
Sea Engineering, Inc. 94	19	Development of a Technique to Identify Pollutant Sources and Impacts in Coastal and Oceanic Waters	$146,000	38103
Sea Engineering, Inc. 94	20	Development of a Broad-band FM Sub-bottom Profiler for Seafloor Imaging and Sediment Classification	$223,870	38109
Science and Technology International, Inc. (STI) 94	21	Hyperspectral Remote Sensing (AAHIS) for Maritime Applications: Phase II	$647,974	38101
Science and Technology International, Inc. (STI) 96	22	Grazing Angle Imaging Lidar (GAIL) for Organic Mine Countermeasure	$698,277	41357
Science and Technology International, Inc. (STI) 95, 96	23	Dual Mode Fluorescence Imaging for Maritime Applications	$894,976 $996,428 **$1,891,404**	39496 41365
Synthetic Technology Corporation 95, 96	24	Bioactive Marine Isonitrile Compounds from Hawaiian Sponges as Models for Synthetic Nontoxic Antifoulant and Antibiotic Agents. Synthetic Analogs, Paint Formulations, and Mechanisms of Action	$155,055 $326,553 **$481,608**	39616 41777
TerraSystems, Inc. 96	25	Development of an Underwater Video Camera for Optical Contrast and Range Enhancement Using Spectral Stretching	$247,323	41358
Thermal Energy Storage, Inc. 96	26	Development and Testing of a Clathrate Desalination Research Facility	$250,000	41367
Varian Associates, Inc. 95	27	Laser Heterodyne Imaging for Shallow Water Surveillance	$299,674	39615

2.0 High-Resolution Bottom-Penetrating Acoustic Sensors and Signal Processing Algorithms for Reduction of False-Alarm Probability in UXO Hunting

ABSTRACT

This project demonstrated increased resolution and reduced false alarm rates for a synthetic aperture sonar (SAS) added to the HAWAII MR-1, a towed sonar array and data processing system owned by the Hawaii Institute of Geophysics. SAS technology uses the forward motion of a small physical array to synthesize a much larger array. The long synthesized array produces a much higher along-track resolution and signal to noise ratio (contrast) than that of the physical array alone. Using SAS technology, the along-track resolution can be made constant independent of frequency and range. As a consequence, lower operating frequencies (lower absorption) can be used in an SAS to increase range or to penetrate the bottom without compromising resolution. This is the first known use of SAS techniques to image buried objects.

During the first year of funding, the data quality suffered from excessive towbody movements caused by the ship's movements. In subsequent years, the towbody was reconfigured to operate either as a heavy tow, or as a neutral tow that decouples the towbody from the ship's motions in heavier seas.

The system was improved significantly from FY94 to FY96. The improvements allow forming a SAS image equivalent to a 9m array which is a 6-fold improvement over the original 1.5m array. The FY96 system gives more resolution, more contrast, and detection of the deepest buried cylinder (2m). The SAS images achieve the 20cm limit set by the array spacing. The simulation results predict "resonances" in man-made cylindrical objects. With the SAS system it is possible to detect these resonances for the targets on the bottom.

The technology has wide potential application and relates directly to emerging programs in mine countermeasure technology at the Office of Naval Research and advanced sonar development at ARPA. Hawaii involvement is very high and potential residual benefits to Hawaii are great. The original contract was let to Alliant Techsystems which was purchased by Hughes Aircraft Company in March 1997. In December 1997 Hughes merged with Raytheon Systems Company.

Contractor: Alliant Techsystems, Inc.
Raytheon Systems Company
6500 Harbour Heights Parkway
Mukilteo, WA 98275-4844
phone: 206-356-3616

Subcontractor: University of Hawaii
HMRG, Post A15
1680 East West Rd
Honolulu, HI 96822
phone 808-956-5232

Principal Investigator: Mr. Dennis Garrood
garrood_@mulkilteo.hac.com

Contract Number:	Contract Amount:	Funding Year
38107	$980,766	FY94
39570	$990,083	FY95
41401	$982,087	FY96

Start Date:
January 1995

Completion Date:
October 1995

September 1995	April 1997
January 1997	February 1998

2.1 BACKGROUND AND TECHNICAL DESCRIPTION

2.1.1 Background

The U.S. Navy needs better detection and more accurate classification of ocean subbottom objects for environmental monitoring and cleanup, in geological surveying, and in unexploded ordnance (UXO) hunting. UXO hunting is a particular concern of the Department of Defense and especially to the State of Hawaii due to its extensive shoreline and history of naval activity. The high false alarm rate experienced in current UXO hunting technology increases the cost of surveys and cleanup operations.

False alarms can be reduced by using higher resolution sonars and a signal processing that characterizes the background clutter as well as the buried objects of interest. Higher resolution sonars provide a better description of rocks, layers, and inhomogeneities that can mimic or camouflage UXO.

Raytheon Systems Co.(RSC) and Hawaii Mapping Research Group of the University of Hawaii have demonstrated that the synthetic aperture developed for radar can be used to improve underwater sonar images. As shown in Figure 2.1, Synthetic Aperture Sonar (SAS) technology uses the forward motion of a small physical array to synthesize a much larger array. The long synthesized array produces a much higher along-track resolution and signal to noise ratio (contrast) than that of the physical array alone. Using SAS technology, the along-track resolution can be made constant independent of frequency and range. As a consequence, lower operating frequencies (lower absorption) can be used in a SAS to increase range or to penetrate the bottom without compromising resolution.

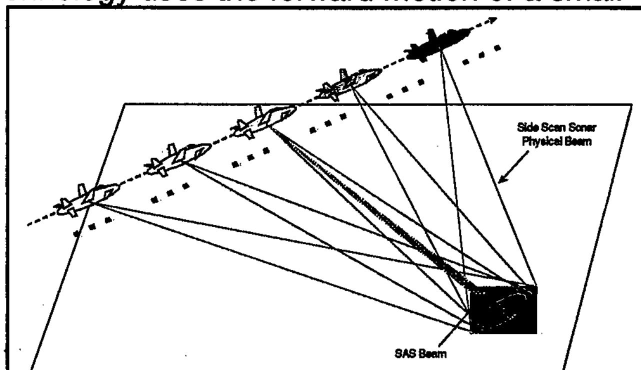

Figure 2.1 Synthetic Aperture Sonar Concept

Hughes Aircraft Company acquired the Marine Systems Division of Alliant Techsystems in March 1997 and the open CEROS contracts were then assigned to Hughes. In December of the same year, Hughes Aircraft merged with Raytheon Systems Company and the former Marine Systems Division of Alliant Techsystems became a part of the Naval and Maritime Systems of Raytheon Systems Company. The open CEROS contracts were then assigned to Raytheon.

2.1.2 Technical Description

The system builds on the HAWAII MR1 bottom mapping system employed by the Hawaii Mapping Research Group (HMRG) of the Hawaii Institute of Geophysics and Planetology (HIGP) of the University of Hawaii School of Ocean, Earth Science, and Technology (SOEST). The HAWAII MR1 (HIG Acoustic Wide Angle Imaging Instrument Mapping Researcher) is a bottom mapping device that features a towbody with low-frequency, side-looking-sonar (SLS), data telemetry, a launch and recovery system, and a topside command, control, and display system. The towfish, shown in Figure 2.2, consists of three acoustic arrays, an inertial measurement sensor (IMU), a depth sensor, signal conditioning, and a telemetry system to transport the sonar and sensor data to the surface. On the surface there are sonar and sensor displays, data logging facilities, and a GPS system for measuring the ship's position.

Parameter	Value	Parameter	Value
Keel Array Element Beam Width	48°H & 60°V	Tow Body Length	5.5m
Keel Array Physical Beam Width	1.5°H	Tow Body Height	1.5m
Keel Array Tilt	30°	Operational Depth	50m
Wing Element Beamwidth	tbd	Pitch Under Tow (Heavy Tow)	1°/kt
Wing Array Physical Beamwidth	tbd	Pitch under tow (Neutral Tow)	0.1°/kt
Wing Array Transmit Beamwidth	tbd	Tow Speed	2 – 10kts
Weight in Water (Neutral Tow)	+25kg	Weight in Water (Heavy Tow)	-1000kg

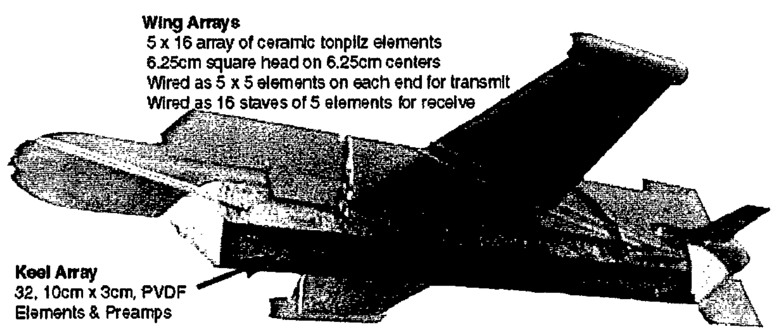

Figure 2.2 UXO Hunting Towfish with Floatation for Neutral Tow and Wings set for Maximum Bottom

2.2 OBJECTIVES

The investigators sought to design, build, and demonstrate a low-frequency bottom-penetrating, side-looking sonar system with synthetic aperture sonar (SAS) signal processing. This SAS would demonstrate increased resolution and reduced false alarm rates over existing systems.

2.3 PROJECT ENVIRONMENT

Alliant researchers designed the system with computer modeling and other engineering tools at their offices in Mukilteo, Washington. HMRG researchers worked in their labs and offices at UH in Honolulu and at the UH Marine Center near Sand Island. The team conducted field tests in the Pacific Ocean nearshore to Waikiki in about eighty feet of water.

2.4 METHODOLODY AND RESULTS

The major tasks were to modify and integrate the data collection hardware and software, develop a SAS data processing algorithm, design and install a field test site, operate the sonar system in the field site, collect and analyze data, and develop a data display algorithm.

In FY94 the HAWAII MR1 was modified to collect differential-phase, side-looking-sonar data from four sonar channels on one side of the towbody. The number of sonar channels was increased to 32 in FY95 and to 64 in FY96. The researchers installed two transmit arrays and a new receive array on one side of towbody. A six degree of freedom inertial measurement (IMU) was installed to measure towbody motion. A CTD (conductivity, temperature, depth) unit was installed to collect environmental information during field tests. The bottom and subbottom acoustics were characterized. The data telemetry software and the topside command, control, and display software was modified to accommodate the modified towbody hardware. The data telemetry rate was increased from 38 Kbytes/sec in FY94 to 6.144Mbytes/sec in FY95 and FY96. Other system features similarly were updated from FY94 (phase 1) through FY95 (phase 2) and FY96 (phase 3) as shown in tables 2.1 and 2.2.

Features	Proof of Principle System (FY1994)	Purpose-Built System (1995/6)
Sonar Channels	• 4 sonar channels, 16 bits each channel • Telemetry rate is 38kbytes/sec Both limited bottom coverage.	• 32 sonar channels, 32 bits/channel • Telemetry rate 6.144Mbytes/sec
Transmit Waveform	• Tone bursts only	• Arbitrary waveforms • Chirps used for increasing SNR • Bandwidth used to increase range resolution and to excite target resonances
Ping Interval	• Minimum ping interval 100ms. Limited speed of advance.	• Minimum ping interval 50ms. • Increases spatial sampling density allowing faster tow speeds
Bathymetry Configuration	• Ping/pong transmit Interferometric Bathymetry system implemented by transmitting alternately from vertically displaced projectors. Porr correlation between pulses limited performance.	Simultaneous transmission of up and down chirp signals from vertically displaced projectors. (Not tested until 1997)

Keel Array Configuration	• 4 elements, 20cm long. Array size limits speed of advance and length of. synthetic aperture.	32 elements, 10cm long. Higher speed of advance and longer synthetic aperture yielding more contrast and resolution

Table 2.1 System Feature Comparison

Feature	Description	Benefit
Telemetry Capacity	• 64 sonar channels with 20 bits dynamic range; 32 channels selectable for logging • Telemetry Rate = 6.144 MBytes/sec for 32 bits sonar samples	• Longer arrays, more complex array configurations and faster tow speeds.
Arbitrary Transmit Waveforms	• The transmit waveform is initialized by loading a pre-computed file during logging software startup	• Tone burst for normal imaging and chirp waveforms for Interferometric Bathymetry.
Ping Interval	• Ping every 50 ms (20 pings/sec)	• Faster tow speeds and more frequent bottom sampling.
Keel Array	• 3.2 meters (or 25.6 wavelengths)	• High contrast, high resolution SLS image
Wing Arrays	• These hydrophones add cross track aperture to the system. The wing angle is adjustable in the field • Large area of ceramic in order to achieve large signal levels without cavitation • Large projector has an inherently small beam pattern, time delays were used to broaden the transmit beam	• Images near tow fish nadir using the new down-looking mode. • SAS images using only wing elements reduce sensitivity to yaw motion and increase directivity in the cross track direction
Receiver Design	• Each hydrophone element is connected to a preamplifier and digitizer	• Preamplifier/digitizer unit converts each hydrophone signal to a digital signal at the earliest possible point to reduce EM pickup • Greatly reduces the cost and volume of the traditional sonar receiver design.
Dual Mode Tow System	• Neutral body towed behind a heavy depressor • Heavy fish towed without a depressor	• Tow configuration can be changed over within few hours to accommodate the sea conditions and survey area..

Table 2.2 Detailed System Features of the Purpose Built SAS Test Bed

The sonar has been designed to operate in several different configurations as summarized in Table 2.3.

Mode	Configuration	Transmit	Receive	Comment
A	Down Looking	Single side (upper or	Double side (both	Down looking geometry to

		lower wing projector; wings set to horizontal)	wings and partial keel)	improve target to backscatter by narrower beams and more energy on target
B	Side Looking	Single side (upper or lower wing projector; wings set at an angle)	Single side (split wing single side plus keel)	Phase comparison for bathymetry by cross correlation of beams; traditional bathymetry, no replica required
C	Side Looking	Single side (upper and lower wing projectors with orthogonal pulses; wings set at an angle)	Single side (full keel)	Phase comparison for bathymetry by replica correlation of beams, transmit grating lobes unattenuated
D	Side Looking	Single side (upper and lower wing projectors with orthogonal pulses; wings set at an angle)	Single side (partial keel + split wing 1 and partial keel + split wing 2)	Replica correlation phase comparison for bathymetry with 2x resolution of mode B
E	Side Looking	Single side (upper and lower wing projectors with orthogonal pulses; wings set at an angle)	Single side (one full wing and partial keel)	Replica correlation phase comparison and beamforming for bathymetry with 2x resolution of mode B
F	Side Looking	Single side (upper or lower wing projector; wings set at an angle)	Single side (one full wing and partial keel)	Beamforming with editing for bathymetry with same resolution as mode B

Table 2.3 Configuration Modes for Sonar Operation

The modes use various combinations of the available 64 sonar channels (a sonar channel is defined as one or more grouped hydrophone elements with signal conditioning electronics that is recorded in real time by the system) to enhance target backscatter against bottom reverberation. Mode A is a downward looking configuration that uses both the upper and lower projectors on the starboard wing to ensonify the bottom surface and the sub-bottom regions below the sonar system platform. The energy scattered back is received and processed with hydrophone elements on both wings and the keel hydrophone. Using the combination of the wing and keel elements in this mode allows for narrower beams both along-track and cross-track, yielding a higher signal to reverberation ratio. Modes B and F are side-looking configurations that use a single transmit projector on the starboard wing and different combinations of hydrophone elements from the starboard wing and the keel hydrophones. Bathymetry processing can be done based on the vertical separations of the wing hydrophone elements and the keel elements. Modes C, D, and E are side looking modes that use simultaneous and orthogonal signal transmissions from the upper and lower projectors on the starboard wing. These modes provide an alternative method for measuring target elevation by dechirping (range compressing) the sonar returns using the two different transmit replicas and cross correlating the dechirped data.

Under subcontracts from Alliant, the test field was installed by Sea Engineering, Inc., with permitting by INTECH, both of Hawaii. The test field was 24 feet wide by 160 feet long and was preceded on the approach end by a 90 foot line of passive acoustic markers. Four target types were used for the test: 1) standard air-filled cylinders (12 in. diameter by 5 ft. long) that simulate a mine casing; 2) small air-filled cylinders (8 in. diameter by 4 ft. long) that provide a lower signal strength than the standard cylinders; 3) air-filled basketballs that act as low target strength point targets; and 4) corner reflectors (12 in. diameter) that provide a high target strength point target. The targets were located by local differential GPS.

Data was processed during the sea test to validate operation of hardware and software data collection. Data was processed post-field work to demonstrate the enhancements of SAS image and 3D display processing.

The system was improved significantly from FY94 through FY96. The improvements allow forming a SAS image equivalent to a 9m array which is a 6-fold improvement over the original 1.5m array. The FY96 system gives more resolution, more contrast, and detection of the deepest buried cylinder (2m). The SAS images achieve the 20cm limit set by the array spacing. The simulation results predict "resonances" in man-made cylindrical objects. With the SAS system it is possible to detect these resonances for the targets on the bottom.

During the first year of funding, the data quality suffered from excessive towbody movements caused by the ship's movements. In subsequent years, the towbody was reconfigured to operate either as a heavy tow or as a neutral tow, depending on sea conditions. The heavy tow, which is easier to handle from most vessels, is used in confined, sheltered waters like Puget Sound. The neutral tow features an added depresser weight to decouple the towbody from the tow vessel motions. The neutral tow is used in open water. The heavy tow is called heavy because it is negatively buoyant in water; the neutral tow is positively buoyant in water. The data improved significantly due to the altered towbody.

Figure 2.3 shows representative data. The top plot represents the plan view of the target field. The left most symbol represents the fourth (last) approach marker (large corner reflector). The standard air-filled cylinders are labeled a1 to a4, c1 to c6, and v1 and v2. Their orientations are indicated by the alphabet in their labels: "a" = aligned in the along axis, "c" = aligned in the cross track axis, and "v" = aligned vertically. About half of the standard cylinders are buried. The air-filled basketballs are shown as blue dots. Small miscellaneous cylinders and spheres are located at the end of the field. The middle plot depicts a conventional SLS image. This image shows some highlights from the targets, but they are not focused and their positions do not correlate well with the target field layout, especially with the alignment of the small cylinders at the end of the field. The SAS image, the bottom plot, has much higher resolution and contrast.

Most targets are focused and localized. All the along-track aligned cylinders are visible while "a3" (buried two feet) showed up as collection of highlights. The small cylinders at the end of the field are aligned as planned.

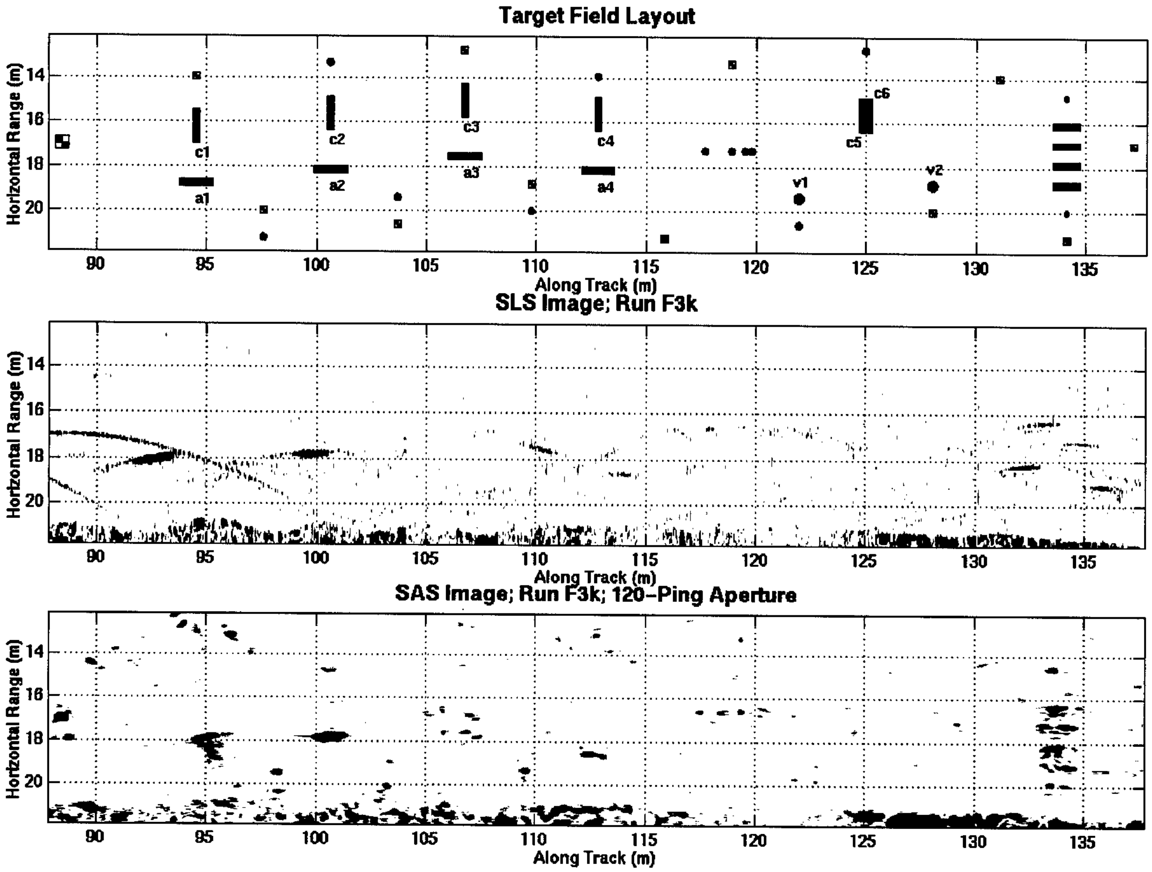

Figure 2.3 Phase 3 System Demonstrated Improved Resolution and Contrast of Buried Targets

2.5 PRODUCTS

2.5.1 Commercial Products

At this time the SAS purpose built, test bed is planned to form the basis for the University of Hawaii HMR2. With some changes to adapt the system to the HMR1 launcher, the system can be deployed from survey ships of opportunity. In addition to deep ocean surveys, HMRG has proposals out with other universities and government institutions to establish SAS as a geophysical research tool for ocean studies.

2.5.2 Papers, Patents, and Disclosures

No invention disclosures or patents have been filed. The following papers were published about this project.

"Acoustic Detection and Classification of Buried UXO Using Synthetic Aperture Sonar." Mark Neudorfer, Dennis Garrood, Norman Lehtomaki, and Tony Luk. Pacific Congress on Marine Science and Technology, 1996 (PACON '96), Honolulu, Hawaii, June 17-22, 1996, p. 10.

"Subbottom Swath Mapping with HAWAII MR1." Mark Rognstad, Oceans 96 MTS/IEEE Conference Proceedings, Sept. 1996, Vol. II, pp1014-1018.

"Test Results for a Special Purpose Synthetic Aperture Sonar." M. Newdorfer, D. Garrood. T. Luk, and M. Nelson. Acoustic Society of America, June 19, 1997.

2.6 IMPACT

2.6.1 Job Creation

In FY94, $356,500 supported subcontracts to Hawaii companies including over $218,000 to HMRG that supported two full-time positions there. At Alliant, over three full-time positions were supported. Various Hawaii companies received subcontracts that supported a few months of work. In FY95, over $462,000 supported subcontracts to Hawaii companies including about $293,000 to HMRG, and in FY96, nearly $400,000 went to Hawaii companies via subcontracts, including $270,000 to HMRG. In each year, two full-time positions were supported at HMRG, and three full-time positions were supported at Alliant.

2.6.2 Business Development

This work is not likely to lead to a commercial product until the system is improved for use at higher towspeeds and faster in-field data processing rates. This work will aid in attracting grants and other funding to the University of Hawaii. Further work to remove the slow tow speed constraint will attract more deep ocean survey work by increasing contrast and resolution ten-fold compared to present day commercial systems.

The DoD is interested in Mine Warfare applications of SAS. The results achieved in this work will lay the groundwork for more advanced DoD systems. The purpose built test bed is ideal for hosting experiments of advanced techniques.

2.6.3 Residual Benefits to Hawaii

Alliant expanded its operations in Hawaii and exchanged technology with its UH HMRG teammates. Alliant established a part-time position in Hawaii to support these contracts. The HAWAII MR1 and all upgrades created during this project remain the property of HMRG at University of Hawaii. HMRG uses the MR1 to conduct scientific research and commercial contracts, both of which bring large amounts of funding to UH.

2.6.4 Principal Investigator/Company Opinion

SAS is a key enabling technology for Mine Warfare products. Presently its application is limited by speed of advance constraints but methods to overcome this limitation have been proposed to the DoD. This technology is the only one identified that will result in the order of magnitude increase in area coverage rate that the DoD is looking for in the detection and classification of mines. The results of this work demonstrate that buried objects can be located and classified as man made or not with increased certainty. This is due to the spatial resolution increase from SAS processing and the contrast increase that enables the detection of target resonances associated with man made, buried objects.

2.6.5 Impact on Principal Investigator/Company

The impact of the CEROS funding has been to allowing pooling of DARPA funding and investment funding so that a full time team, all experts in synthetic aperture processing, could be formed and maintained intact for the last five years. The resulting synergy has allowed SA to develop more quickly for each of the projects associated with the funding.

2.7 TRANSITION

CEROS awarded $758,000 in FY97, $550,000 in FY98, and $865,631 in FY99 to continue this work. At the end of calendar year 1995, DARPA awarded a contract to Alliant for related SAS work.

3.0 Naturally Occurring Antibodies From Marine Algae Chaetoceros

ABSTRACT

In a breakthrough discovery, Aquaculture Technology, Incorporated (ATI) has isolated some naturally-occurring antibacterial compounds from the marine algae *Chaetoceros spp.*. Aquaculturists had observed that certain algae could be maintained in a pure culture without the addition of antibiotics. Dr. Wang hypothesized that something in the alga itself acted as an antibiotic to prevent growth of other organisms. He identified several polyunsaturated fatty acids in the chemical composition of *Chaetoceros spp.*. He then demonstrated that these compounds are effective against *Vibrio vulnificus*, *Listeria monocytogenes*, methicillin-resistant *Staphylococcus aureas,* vancomycin-resistant *Enterococcus* and other bacteria in *in vitro* tests. ATI contacted Tripler Army Medical Hospital in Honolulu and Walter Reed Army hospital in Washington to review research methods and results.

The discovery of new antibacterial substances from marine algae provides at least two avenues for commercialization: to license the production of the antibiotic, and to supply the algae to the pharmaceutical company for the production of antibiotics.

These compounds are nearly impossible to synthesize, so large quantities of *Chaetoceros spp.* will need to be grown for drug production. Dr. Wang developed a revolutionary open system for large-scale production of marine microalgae without innoculation. The continuous marine algae production system will have applications beyond the supply of algae for medical purposes. Marine microalgae provide many important industrial products like food pigments and biosurfactants with billion dollar world markets.

Contractor: Aquaculture Technology, Inc.Subcontractor: none
455 Anolani Street
Honolulu, HI 96821-2032
phone: 808-377-5087

Principal Investigator: Dr. Jaw Kai Wang
Email: aquatech@ceros.org

Contract Number:	Contract Amount:	Funding Year
38080	$171,485	FY94
39604	$206,960	FY95

Start Date:	Completion Date:
November 1994	October 1995
September 1995	October 1996

3.1 BACKGROUND AND TECHNICAL DESCRIPTION

3.1.1 Background

DoD needs antibiotics to prevent wound sepsis in battlefield and training injuries. *Staphylococcus spp.* infections present a major public health concern in Hawaii. New strains of *Staphylococcus spp.* have been reported in Japan and in the United States that are resistant to all approved antibiotics so new drugs are needed for military and public use.

Aquaculturists had observed that certain algae could be maintained in a pure culture without the addition of antibiotics. Dr. Wang of Aquaculture Technology, Inc. (ATI) hypothesized that something in the algae itself acted as an antibiotic to prevent growth of other organisms. He discovered several polyunsaturated fatty acids in the chemical composition of *Chaetoceros spp.*. He then demonstrated that these compounds are effective against MRSA, vancomycin-resistant *Enterococcus* (VRE), and several other bacteria in *in vitro* (test-tube) tests.

A major difficulty in making use of naturally occurring substances is to produce the substance in large enough quantities at a competitive price. Because the compounds cannot be easily synthesized, the natural source will be utilized. Aquaculture Technology Inc. is optimizing a large-volume production system for growth and harvest of *Chaetoceros sp.*.

3.1.2 Technical Description

ATI researchers have isolated and identified naturally-occurring chemicals from the marine algae *Chaetoceros sp.* that demonstrate antibacterial activity. It is possible that these chemicals could comprise a new antibiotic for human use. The chemical structures are shown in Figure 3.1.

$C_{16}H_{26}O_2$ (Z,Z,Z)-6,9,12-Hexadecatrienoic acid (16:3Δ6,9,12)

$C_{16}H_{28}O_2$ (Z,Z,Z)-9,12-Hexadecadienoic acid (16:2Δ9,12)

$C_{20}H_{30}O_2$ (Z,Z,Z,Z,Z)-5,8,11,14,17-Eicosapentaenoic acid (20:5Δ5,8,11,14,17)

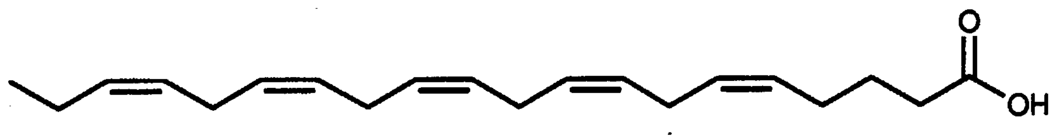

Figure 3.1 The chemical structures of three fatty acids isolated from *Chaetoceros*, *Thalassiosira*, *Phaedactylum*, and *Navicula* species.

ATI researchers developed an open system for mass production of marine algae that is faster and cheaper than traditional methods. The system uses tall, round, transparent, plastic columns (18 in. diameter by 5 ft. tall) plumbed for carbon dioxide input, aeration by compressed air, with automated pH adjustments to optimize growth, and foam fractionation to harvest the algae. Figure 3.2 shows a photograph of the algae production columns at NELHA in 1995.

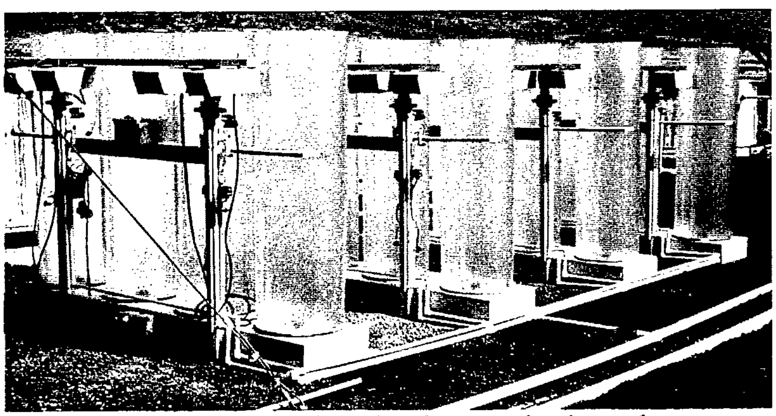

Figure 3.2 Photograph of the algae production columns.

3.2 OBJECTIVES

The project objective was to identify and characterize antibacterial properties of *Chaetoceros spp.*, *Phaedactylum tricornutum*, and *Navicula spp.*, and to develop a large-volume production system to grow and harvest marine algae.

3.3 PROJECT ENVIRONMENT

ATI researchers grew the algae at the Natural Energy Laboratory of Hawaii Authority (NELHA) at Keahole Point, Hawaii, on the rooftop of the University of Hawaii, and at the ATI production facility in the Anuenue Fisheries Laboratory, Department of Land and Natural Resources on Sand Island, Oahu. The large-scale open production system was developed at NELHA and moved to Sand Island in August 1995.

ATI researchers worked at University of Hawaii-Manoa laboratories for the chemical separation, chemical identification, and determination of antibacterial activity.

3.4 METHODOLOGY AND RESULTS

The algae were cultivated in tall, round, transparent plastic columns that measure 18 in. diameter by 5 ft. tall. The columns are located outdoors in natural sunlight and exposed to the ambient atmosphere. The columns are filled with natural seawater, and then water from an oyster farm is introduced to innoculate the column with a natural community of algae. Some nutrients are added. The growth conditions (pH, shaded/direct sun, nutrients, temperature) are adjusted to favor a given species of alga until the culture nears 95% purity. Through scientific trials, ATI researchers determined the most favorable conditions for each of the species of interest (*Chaetoceros spp.*, *Phaedactylum tricornutum*, and *Navicula spp.*) and codified these culture methods.

This is an innovative approach to algae production. In the traditional method, a pure strain of a given species is raised in a test tube. Through many labor-intensive steps, the algae is multiplied in near-sterile conditions. Due to the conditions, the algae do not need to fight off bacteria so they likely produce less of the desired chemicals. Compared to the traditional method, the ATI method is faster and cheaper, and produces strong, bacteria-resistant algae.

ATI developed the procedure for isolating the active fatty acid from the algae. Each day around sunset the algae are harvested by foam fractionation. The algae are ground to a wet algae paste, taken into water, and centrifuged to obtain a supernatant liquid. The supernatant liquid is loaded onto a chromatography column and eluted with an aqueous gradient eluant. To separate the chemical constituents that comprise the algae, the paste is extracted with organic solvents into nine or ten fractions. Each fraction is tested for antibacterial activity. When a fraction shows antibacterial activity, the fraction is further separated by high-pressure liquid chromatography (HPLC). Individual chemicals are identified by nuclear magnetic resonance (NMR).

ATI researchers identified three specific compounds that exhibit antibacterial activity. These compounds are the fatty acids (Z,Z,Z)-6,9,12-Hexadecatrienoic acid (16:3Δ6,9,12), (Z,Z,Z)-9,12-Hexadecadienoic acid (16:2Δ9,12), and (Z,Z,Z,Z,Z)-5,8,11,14,17-Eicosapentaenoic acid (20:5Δ5,8,11,14,17). In 1996 ATI filed a patent application for use of the two C_{16} fatty acids as antibacterial agents for mammals and for aquaculture.

ATI researchers tested four species of algae to determine whether they contain the antibacterial compounds. The results are listed in table 3.1.

Table 3.1 Algae Species Tested and Antibacterial Fatty Acids Isolated
+ compound isolated from algae extract
- compound not found in high quantities in algae extract

Algal Species	(Z,Z,Z)-6,9,12-hexadecatrienoic acid	(Z,Z,Z)-9,12-hexadecadienoic acid	(Z,Z,Z,Z,Z)-5,8,11,14,17-Eicosapentaenoic acid
Chaetoceros	+	+	-
Thalassiosira	+	+	+
Phaedactylum	-	-	+
Navicula	+	+	+

The tests for antibacterial activity were conducted in the University of Hawaii laboratory of Dr. Sophia Kathariou because it is certified for work with virulent pathogens. A disc of filter paper containing the chemical to be tested is placed into commercially-available petri dishes containing the bacteria of interest. The chemical seeps into the agar where it can affect the bacteria. If the area around the disc clears, then the chemical is effective against that bacteria. The results are presented in table 3.2.

Table 3.2 This table indicates the effectiveness of the isolated compounds against selected bacteria and fungi. The compounds tested were (Z,Z,Z)-6,9,12-Hexadecatrienoic acid (16:3Δ6,9,12) (C_{16} Trienoic), (Z,Z,Z)-9,12-Hexadecadienoic acid (16:2Δ9,12) (C_{16} Dienoic), and (Z,Z,Z,Z,Z)-5,8,11,14,17 -Eicosapentaenoic acid (20:5Δ5,8,11,14,17) (C_{20} Pentaenoic). A plus (+) sign means the fatty acid is active against the bacterium or fungus while a minus (-) sign means not active. An "nt" means the compound was not tested against that bacteria. The concentration used was 100μg/disk.

Bacterium	C_{16} Trienoic	C_{16} Dienoic	C_{20} Pentaenoic
Shigella dysenteriae	+	-	nt
Bacillus subtilis	+	+	+
Salmonella typhimurium	-	-	nt
Lysteria monocytogenes	nt	+	nt
Klebsiella pneumoniae	-	-	nt
Methicillin resistant staphylococcus aureus (MRSA)	+	+	+
Vancomycin resistant enterococcus (VRE)	+	+	+
Pseudomonas aeruginosa	-	-	-
Micrococcus smegmatis	+	+	nt
Micrococcus luteus	+	+	nt
Streptococcus pyogenes	+	+	nt
Proteus vulgaris	+	+	-

Corynebacterium xerosis	+	+	+
Bacillus cereus	+	+	+
Corynebacterium diptheriae	+	+	nt
Streptococcus mitis	+	+	+
Streptococcus faecalis	+	+	+
Streptococcus typhimurium	nt	nt	-
Streptococcus pneumoniae	nt	nt	-
Staphylococcus epidermidis	+	+	nt
Vibrio vulnificus	+	+	+

Fungi	C_{16} Trienoic	C_{16} Dienoic	C_{20} Pentaenoic
Aspargillus niger	+	+	-
Candida tropicalis	+	+	-
Candida glabrata	+	+	+
Rhodotorula rubra	+	+	-
Trichosporon beigelii	+	+	-
Candida albicans	+	-	-

ATI conducted preliminary cytotoxity tests on mouse fibroblasts and no cell damage resulted, i.e. the test for cytotoxity was negative.

3.5 PRODUCTS

3.5.1 Commercial Products

No commercial products have resulted as of this time. The company has intellectual property from the project.

The discovery of new antibacterial substances from marine algae provides at least two avenues for commercialization: to license the production of the antibiotic, and to supply the algae to the pharmaceutical company for the production of antibiotics. Also, the continuous marine algae production system will have applications beyond the supply of algae for medical purposes. Marine microalgae provide many important industrial products like food pigments and biosurfactants with billion dollar world markets.

3.5.2 Papers, Patents, and Disclosures

Per attorney advice, the principal investigator has not published this work pending patent approval and investor negotiations.

On February 2, 1999, the principal investigator received U.S. patent number 5,866,150 entitled "Antibacterially Active Extracts from the Marine Algae Chaetoceros and Methods of Use." The patent was filed March 20, 1996, the inventor is Jaw Kai Wang, and the patent owner is Aquaculture Technology, Inc..

3.6 IMPACT

3.6.1 Job Creation

The CEROS contract supported two new positions at ATI during FY94 and FY95. A full-time engineer and a full-time laboratory assistant were hired to cultivate and harvest the algae, extract the chemical fractions, and identify the chemicals of interest. These positions were replaced by other positions in the following years. Partial stipends for three existing University of Hawaii researchers (including the principal investigator) were supported by the contract during FY94 and FY95.

3.6.2 Business Development

There are no sales to date because development of a new medicine is lengthy and expensive. ATI contacted Tripler Army Medical Hospital in Honolulu and Walter Reed Army hospital in Washington to review research methods and results. ATI is seeking investors to support improvements to the chemical extraction techniques and to continue the medical trials.

3.6.3 Residual Benefits to Hawaii

Aquaculture Technology, Inc. is bringing investors to Hawaii to join in this venture. Although this project is too early in the development stage to realize the benefits to Hawaii, the potential economic return is very large. This project adds to Hawaii's growing reputation as a world class biotechnology incubator.

3.6.4 Principal Investigator/Company Opinion

Dr. Wang reported that doing business with CEROS is better than with any other funding agency he has experienced over decades of research and development. The CEROS program requirements are clear-cut, funds are received in a timely fashion, and the staff is responsive, efficient, and helpful. In contrast to other programs, the CEROS contract required only a minimum of reports and other documentation that take time and do not contribute to results.

3.6.5 Impact on Principal Investigator/Company

Without the CEROS funds, ATI could not have done any of the drug research.

3.7 TRANSITION

ATI received $240,000 of CEROS funding in FY97 to continue to improve the production and extraction techniques. Based on results from the CEROS contract, ATI received $107,000 from the rural economic transition assistance Hawaii (RETAH) program.

Due to the significance of ATI's *in vitro* results, the Department of Defense agreed to contribute the next step of the research. In 1997, 1998, and 1999, *in vivo* tests were conducted by Dr. Catherine Uyehara, Director of Collaborative Research at Tripler Army Medical Center on Oahu. The *in vivo* tests demonstrated the efficacy of the compounds against MSRA.

ATI has approached Smith Klein Beecham for commercialization of the compounds.

4.0 Design And Deployment Of A Fiber-Optic Based Autonomous Buoy For In-Situ Monitoring Of Ph, Pco2, Temperature, O2, And Water Quality In Seawater (Phase II); And Solution+ In-Situ Ocean Sediment Chemical Analyzer

ABSTRACT

Detection Limit Technologies, Inc. (DLT) demonstrated for the first time the ability to detect oxygen in seawater based on the molecular composites incorporating tailored excited states of transition metal complexes and thin mono and multilayer films. To achieve this breakthrough technology, DLT developed a unique metal coating for the sensor. DLT developed a new palladium-porphyrin complex, immobilized a platinum porphyrin in a film of polycarbonate on a fused silica surface, and demonstrated oxygen sensitivity behavior of the coating. The dye is not susceptible to photobleaching and is particularly amenable to low-power, diode-based laser sources that would be required to use the instrument on a robust, remote ocean data buoy. This development allowed DLT to use Raman spectrographic techniques to measure oxygen. The original plan to deploy and test instruments on buoy purchased from Woods Hole Oceanographic Institution was modified because of delays at Woods Hole in buoy development. DLT demonstrated alternative test scheme using instruments deployed from Makai Research Pier, Waimanalo, O'ahu in December 1995.

In FY96, DLT improved the *Solution* instrument by adding a fluorescence mode to the Raman system. The improved instrument, trademarked *Solution+,* incorporated an ultraviolet excitation capability that allowed collection of Raman and fluorescence data simultaneously. The fluorescent capability increased the instrument's capability to detect additional classes of hydrocarbons (e.g. phenols) and to monitor and map site contamination directly using sediment probes. DLT developed stable Raman surfaces that could detect TCE in the 10 ppm range without interference from fluorescence, and to detect particular heavy metals down to 50 ppB. The *Solution+* is a rugged and versatile instrument with applications in environmental monitoring, process control and teaching. DLT miniaturized the probe of the *Solution+* to fit into the SPAWARSYSCEN cone penetrometers to assess environmental contamination at DoD sites in an efficient and cost-effective manner. DLT has used CEROS developmental support to develop a variety of specialized measurement and control instruments based on the *Solution* and *Solution +* prototypes. DLT is actively marketing the commercial versions of the *Solution* and *Solution +* instruments for diverse applications.

Contractor: Detection Limit Technology, Inc.
Post Office Box 1665
Kailua, HI 96734
phone: 808-263-2364

Subcontractor: Dr. Keith Carron
University of Wyoming
Laramie, Wyoming

Principal Investigator: Dr. Christian Schoen
Email: chschoen@dlimit.com

Contract Number:	Contract Amount:	Funding Year
38194	$331,800	FY94
41282	$320,000	FY96

DARPA GRANT NO. MDA 972-94-1-0010
FINAL TECHNICAL REPORT

Start Date:	Completion Date:
December 1994	May 1996
October 1996	March 1998; addendum April 1999

4.1 BACKGROUND AND TECHNICAL DESCRIPTION

4.1.1 Background

In detecting and identifying compounds, the two most powerful methods are Raman scattering and fluorescence. The Raman effect is a phenomenon where a small fraction of incident (laser) light is converted from its original frequency to another frequency shifted by an amount determined by molecule vibration in the medium. Fluorescence is a phenomenon where laser light collides with neutral atoms and delivers enough energy to excite the atoms to higher quantum levels. Though not as selective between compounds as Raman scattering, fluorescence can be used for detecting fluorescent materials. The detection of normal Raman scattering involves a monochromatic light source (laser), a dispersive optical system (spectrograph), and a sensitive detector (photomultiplier or charge-coupled device (CCD)). Even with high-powered lasers and single photon detection, normal Raman is not a sensitive analytical tool. Using Raman scattering and fluorescence technology, Detection Limit Technology, Inc. (DLT) generated a portable microscope—the remote luminescence probe (RLP), which can be used for remote *in situ* monitoring through long fiber lengths for contaminated field-site characterization, process control, and medical applications.

The Solution^{+TM} series of Raman spectrometers uses chemical-specific coatings on the detection surface to greatly enhance the sensitivity; thus the name "surface-enhanced Raman spectroscopy" (SERS). Detection Limit Technology has developed unique coatings to detect and identify several

Figure 4.1 Photograph of Solution 852 Raman System

chemical groups including nitrates, chlorinated hydrocarbons (TCE), heavy metals, and volatile organic carbons (VOCs).

4.1.2 Technical Description

The Solution^{+TM} system is comprised of a laser, an imaging spectrometer, a charge-coupled device (CCD), and a fiber-optic remote probe with macro and micro lens adapters for working distances from 0.25 inches to 25 feet. The system is compact and ruggedized for easy transport. These ordinary components have been combined to provide extraordinary performance which exceeds previous detection limits by orders of magnitude.

4.2 OBJECTIVES

The FY94 project continued development of the FY93 project to design, build, and test a SERS device to measure pH and CO2 in seawater. The FY96 project sought to create SERS coatings to measure trichloroethylene (TCE) and heavy metals for use in environmental monitoring and cleanup of contaminated sediments.

4.3 PROJECT ENVIRONMENT

The device was designed and built in a laboratory environment in Honolulu and Laramie, WY. Field demonstrations were conducted off the Makai Research Pier in Waimanalo and at Alameda Naval Shipyards in Alameda, CA.

4.4 METHODOLODY AND RESULTS

Oxygen Sensing with Thin Layers of Transition Metal Complexes

The purpose of this research was to determine if a sensor for oxygen could be made based on a platinum porphyrin (PtTTP) compound impregnated polymer film. Similar porphyrin compounds centered on ruthenium have been produced which undergo luminescence quenching in the presence of oxygen. This new platinum porphyrin compound exhibits a very marked luminescence quenching *in the* presence of oxygen. For the purposes of this sensor, this compound was immobilized with polycarbonate resin onto quartz slides. The polycarbonate resin is known to be gas permeable, even in liquids, which allows dissolved gasses, such as oxygen, access to the platinum porphyrin compound. The following experiments were devised to test the immobilized compound for its ability to determine the presence of oxygen in water. First, the PtTTP-resin films were produced and cast on quartz slides which were tested against solutions of water enriched in nitrogen (little oxygen), air (about 20% oxygen), and in oxygen (about 90% oxygen) to determine the response of the luminescence signal with these three solutions. Second, the films themselves were tested for durability to exposure to water over a period of time. A third experiment used the film to follow

the diffusion of oxygen in air past the film in solutions enriched in-oxygen and nitrogen to determine the response of the compound without the interference of exposure of the films to the atmosphere during the sample change procedure.

Biofouling Resistance

The inhibition of copper corrosion by polybenzimidazole and mercaptobenzimidazole at room and high temperature has been assessed by SERS and cyclic voltamettry (CV). It has been found that a very compact protective layer, produced by immersion in a polybenzimidazole and mercaptobenzimidazole mixture solutions, showed better anticorrosive performance than each single inhibitor component even at high temperatures. This synergetic effect of the two components is explained by the physico-chemical mechanism of corrosion inhibition of polymeric coatings.

Mercaptobenzimidazole (MBIH) is a powerful corrosion inhibitor for copper immersed in solution, i.e. metal attack by a variety of corrosive media is strongly reduced in the presence of MBIH. Early studies of its chemical behavior on copper surfaces did not reveal the exact inhibition mechanism. Recently there has been great emphasis in using polymers as corrosive inhibitors, for example, different heterocyclic polymers, polythiopropinate, polymaleic acid and polyalkloamide/alkenyl copolymers were developed for protecting steel in seawater. Relatively few polymeric inhibitors for copper have been reported. PBIMH mixed with MBIH, is preferred due to its imidazole rings which tend to form complexes with the metal surface. The polymer can easily form thin films of relatively higher stability than small molecules on the copper surface. It is known that the higher stability would enhance adhesion of the film to the substrate.

By installing the single monolayer coatings on copper, we can leach the copper ions at regulated rates into the sensor head. This system may "poison" any biofouling in the sensor mechanism.

Oxygen Sensing Results

For all of the experiments in this study, preparations of platinum tetratolylporphyrin were dissolved with polycarbonate resin in methylene chloride and were spin cast into a thin layer on a quartz plate. The quartz plates were placed into a quartz cuvette at an appropriate angle with the film facing the detector and the cuvette was then filled with distilled water at equilibrium with air, nitrogen or oxygen. The system was then analyzed by florescence spectroscopy. The results of the first experiments indicated that the luminescence signal of the individual films changed markedly with oxygen content of the solution surrounding the thin film, but that procedural and experimental factors affecting the solution around the film caused varying results in the intensity of the luminescence signal. In addition it was found that the change in luminescence intensity with exposure to the differing solutions was already completed during

the time it took to change the sample and take a spectrum, indicating that the response is shorter than the ten second sample change-over period. The second experiments, in which the films were immersed over a period of time suggested that the films were stable to immersion in both distilled and salt water for a period of two weeks. When air was allowed to diffuse through the water solution, the luminescence signal was found to increase or decrease in a curvilinear fashion. The films were found to be stable over time to both air and to water and salt water.

To adapt SERS for the detection of TCE, DLT tested pentachlorothiophenol, a coating material available commercially from TCI Chemicals. The chlorinated phenyl ring of PCTP should have similar cohesive forces as the highly chlorinated ethylenes like TCE.

To quantitate TCE, one plots the ratio of the 625 cm^{-1} TCE Raman feature and the 675 cm^{-1} internal standard Raman feature of PCTP as shown in Figure 4.2. The shape of the plot, an isotherm, indicates that the system is highly nonideal because the coating is not optimally matched to TCE. An ideal isotherm would level off at high TCE concentrations on the surface. This isotherm indicates an adsorption process where the surface is becoming more attractive to TCE as the concentration builds up. An improved coating would increase sensitivity of a SERS detector for cone penetrometry.

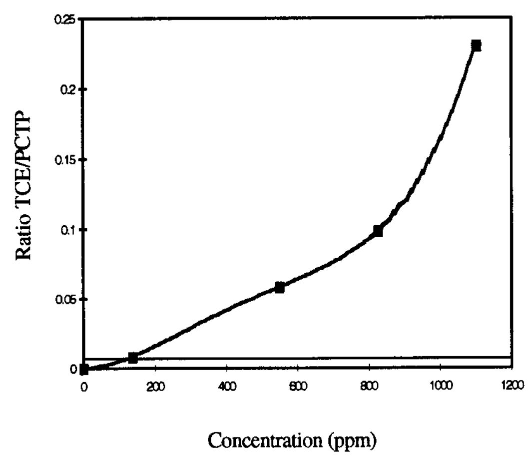

Figure 4.2 Calibration curve for TCE in water.

Heavy Metal Detection

To adapt the SERS sensor for heavy trace metal detection, DLT used a disulfide-modified 4-(2-pyridylazo)resorcinol (PAR disulfide) as a bound metal ion indicator. The absorption of metal ions was followed by correlating the intensity ratio of a Raman band sensitive to metal coordination and its counterpart in the uncomplexed indicator. This approach provides an internal standard and corrects for changes in laser power or the substrate.

The coordination of PAR disulfide with metal ions is very pH dependent so DLT obtained absorption isotherms at pH 3-6. The isotherms were fit to a Frumkin isotherm to account for coverage-dependent electrostatic repulsion. In order to combine the results with accepted analytical formulations, DLT interpreted the data as conditional formation constants. The conditional formation constants allow one to calculate partition coefficients and sensitivity ties at any pH. The dynamic response of the SERS indicator was tested using a fiber-optic flow system. It was found that the system responded in less than 60 s

or in this case the integration time required for the spectroscopic measurement. The use of an optical fiber configuration also demonstrated the potential of this method for in situ monitoring of groundwater metal ion contamination.

This work represents an advance in the use of SERRS to detect metal ions. In DLT's previous work with Eriochrome Black T, they extracted the metal ion complex and spun coat it onto a silver surface. Detection limits for Cd^{2+} 100 ppb for 100 s integration times. In this work, DLT showed that an indicator can be chemically bound to a surface through a thiolate linkage. The detection limit for Cd^{2+} was higher than EBT (50 ppb in 10 s). Future work will be directed at the use of chemometric techniques to utilize the differences in the SERRS spectra to allow both quantitation and speciation of metal ion mixtures.

For this CEROS project, DLT designed and developed a micro-probe and integrated it into the U.S. Navy's Cone Penetrometer. For solid, highly scattering surfaces such as the SERS substrates that were used for this project, or where working distances between probe and surface are required, or where long fiber-optic lengths are needed, a two fiber probe is optimal. To fit in the Cone Penetrometer, DLT reduced the size of the fiber-optic Raman probe. Prior to this project, the smallest two-fiber Raman probe commercially available was part of DLT's Solution system and it measured approximately 2" in diameter. DLT re-engineered it to achieve a diameter of 0.625". Figure 4.3 shows a photograph of the Micro Raman probe.

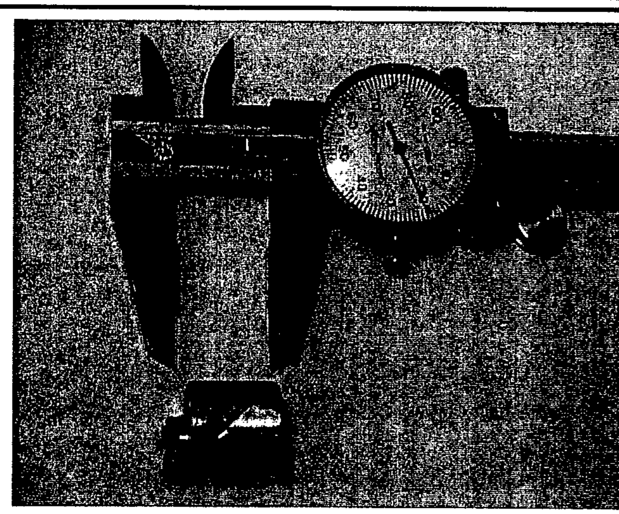

Figure 4.3 Photograph of Micro Raman Probe

The cone penetrometer pulls samples up the sample tube to the surface at depths as great as 180 feet. The addition of the DLT Raman SERS sensor allows for immediate measurements in real-time during the push phase of the cone penetrometer. Without real-time measurements, the cone penetrometer operator is operating "blind" to find contaminants. Figure 4.4 shows the schematic drawing of the ConeSipper, a cone penetrometer manufactured by Vertek, Inc.

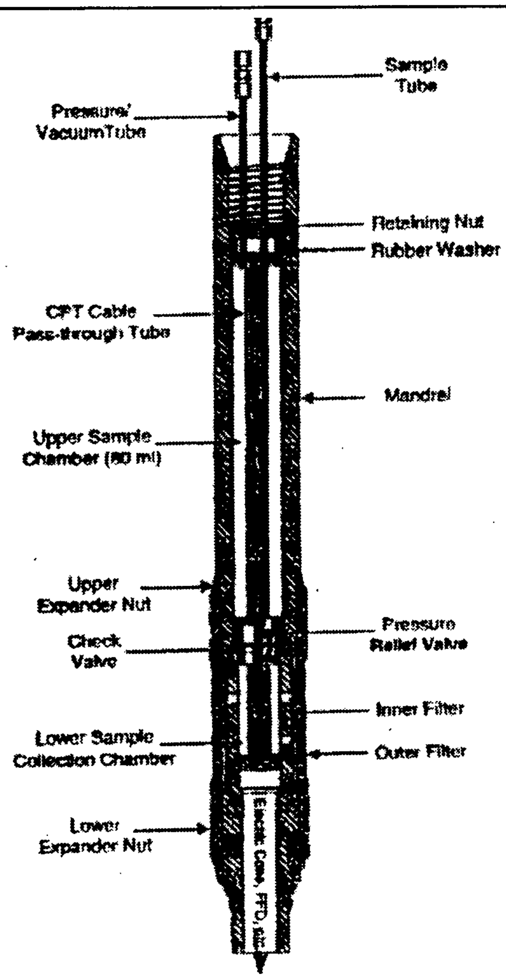

Figure 4.4 Schematic representation of ConeSipper

4.5 PRODUCTS

4.5.1 Commercial Products

Detection Limit Technology Inc. developed a unique optical spectrometer that makes both Raman and fluorescence-based measurements of sediments simultaneously. The Solution^{+TM} series of Raman spectrometers uses chemical-specific coatings on the detection surface to greatly enhance the sensitivity; thus the name "surface-enhanced Raman spectroscopy" (SERS). Detection Limit Technology has developed unique coatings to detect and identify several chemical groups including nitrates, chlorinated hydrocarbons (TCE), heavy metals, and volatile organic carbons (VOCs). There are now several models available including the Solution 852 that uses a 100 mW 852 DBR diode laser as the source. Applications include environmental monitoring, environmental cleanup, and optimization of chemical manufacturing like ammonium nitrates for fertilizer and explosives. The savings can be significant as Detection Limit Technology predicts that their instrument will save $1M per year at a given nitrate plant.

4.5.2 Papers, Patents, and Disclosures

The oxygen sensor is proprietary. Much of the hardware and optical design developed in the Solution Fiber-Optic Raman system remains proprietary, including the ESD design for the diode laser and its power supplies, and the optical layout of the remote probe. DLT trademarked the name Solution^{+TM} through use in commerce and has successfully defended it against similar product names. DLT has two provisional process patents on this work that were filed in October 1998. The following paper was published on this work.

Improving SERS for better sensors. Hillary L. MacDonald, Ralph C. Jorgenson, Christian L. Schoen, Barbara F. Smith, Sinclair S. Yee, Ken I. Mullen. International Symposium on Optics, Imaging, and Instrumentation: Chemical, Biochemical, and Environmental Sensors VI, SPIE Proceedings Vol. 2293, 1994.

4.6 IMPACT

4.6.1 Job Creation

The FY94 effort supported two engineers, one chemist, one production technician, and one administrative person. The chemist was located in Wyoming, and the other jobs were in Hawaii.

The FY96 effort supported two engineers, one chemist (in Wyoming), and one administrative person.

4.6.2 Business Development

The principal investigator has actively pursued many markets for the SERS instruments. While the military sector will benefit from the Solution^{+TM} system, the commercial markets also abound. The uses range from teaching to process control. Several universities have purchased the Solution^{+TM} system including the University of Wyoming and Old Dominion University. Exxon bought a system to improve their corporate research and development efforts.

The system can monitor and control manufacturing processes. Examples include polystyrene manufacturing in New York, octane monitoring in a gas refinery in Kentucky, and natural gas pipeline monitoring in Wyoming. Dr. Schoen is currently working with an ammonium nitrate producer in Cheyenne, Wyoming to put Solution^{+TM} systems into the manufacturing line to provide twenty-four hour production information. By providing tighter production controls, the system may save the company more than $1 million dollars per year and will result in a superior product.

Detection Limit Technology is also exploring medical applications in the area of combinatorial chemistry. When SERS is coupled to immunoassay, combinatorial chemistry can be used to automate methods for rapid screening of samples in a microtiter plate format. One use of this system is to test human fluids for trace amounts of drugs.

4.6.3 Residual Benefits to Hawaii

The most obvious residual benefit is the ongoing jobs. The chassis and anodizing are designed in Hawaii but manufactured elsewhere because the capability does not exist in Hawaii. Electronic board manufacturing and machining are done in Hawaii. As a result of DLT's requirement, a small machine shop opened nearby primarily to provide its machining. That shop is now marketing for business other than DLT.

4.6.4 Principal Investigator/Company Opinion

The principal investigator suggests that further funding not be restricted to ocean R&D, but branch out into all water applications because he believes this could widen the commercial base of resulting development; e.g., groundwater cleanup efforts.

4.6.5 Impact on Principal Investigator/Company

During its first 3 years in business, DLT experienced a lot of gross sales but zero profit. CEROS and SBIR funding (and HI state SBIR matching) has supported all of the development costs.

4.7 TRANSITION

CEROS awarded $360,000 in FY97 and $380,000 in FY98 to adapt SERS to other applications. See also section 4.6.2 Business Development.

5.0 HIRADSIM Workstation Development Project. Continuation of Existing Work Advanced HIRADSIM Small Target, Time Domain, Maritime Radar Mode

ABSTRACT

Hawaii Radar Simulator (HIRADSIM) is an engineer's radar detection slant tracker design tool. The HIRADSIM model runs on a IIP UNIX or an HP 712/60 workstation and is mostly written in C+ except for the radar cross-section model, which is written in FORTRAN. The output of the model provides a radar engineer with the ability to make predictions of received radar-signal strength as a function of various marine environments including rain and sea state. The model is a basic research tool to help design better radar-detection technology for the small targets like instrument masts (periscopes), small boats, and ships that have special wake considerations. Gateway Technologies International Incorporated (GTII) validated the HIRADSIM model and demonstrated the model's effectiveness on a workstation platform, to realize the advances made in radar sensor data fusion and environmental modeling in the FY93 program. Work focused on practical applications of HIRADSIM and included comprehensive tests, evaluations, and demonstrations for qualified technical observers. GTII developed the graphical user interface and integrated it in the workstation. HIRADSIM was tested at the Pacific Missile Test Facility in conjunction with large-scale radar evaluations conducted by NRaD, San Diego laboratory. The workstation-oriented, time domain radar simulator has been improved with a larger area of consideration and reduced computational time (4 to 5 times faster). HIRADSIM demonstrates credibility and internal program capability for GTII and CEA Technologies, Inc., and commercialization is possible for specific applications. GTII and CEA Technologies, Inc. met both the technical and commercial objectives of this effort, namely developing an advanced radar simulator.

Contractor: Gateway Technologies International, Inc.
1188 Bishop Street
Suite 3406
Honolulu, HI 96813
phone: 808-537-5522

Principal Investigator: Mr. Roger Webb
gtiirw@aol.com

Contract Number:	Contract Amount:	Funding Year
38108	$250,000	FY94

Start Date:	Completion Date:
November 1994	April 1997

5.1 BACKGROUND AND TECHNICAL DESCRIPTION

5.1.1 Background

Under CEROS FY93, the Hawaii Radar Simulator (HIRADSIM) was designed to simulate small-target detection in a sea-clutter environment. The project seeks to stimulate research and development (R&D) in areas that lead to commercialization for support of military and commercial applications in designing and developing maritime radar systems.

The contractors shifted during the course of the work. This project began in FY93 as a joint development effort between CTA, Inc., of Englewood, Colorado, and CEA Technologies Pty. Limited, of Canberra, Australia. Gateway Technologies International, Inc. (GTII), of La Jolla, California and Honolulu, Hawaii, provided the management and marketing resources for the program. CEA provided significant intellectual property and techniques. INTECH, Inc., of Honolulu provided engineering services. During FY94, CTA withdrew from the contract and GTII assumed the primary role.

5.1.2 Technical Description

HIRADSIM is an engineer's radar detection slant tracker design tool. The HIRADSIM model runs on a IIP UNIX or an HP 712/60 workstation and is mostly written in C+ except for the radar cross-section model, which is written in FORTRAN. The output of the model provides the radar engineer with the ability to make predictions of received radar-signal strength as a function of various marine environments including rain and sea state. The model is a basic research tool to help design better radar-detection technology for the small targets like instrument masts (periscopes), small boats, and ships that have special wake considerations. Three models were completed: the sea state model, the environmental model, and the periscope model. The models were integrated into a design tool for the radar engineer. The system can model the wake of a vessel, and the stealth properties of a periscope (radar absorbing material and transmission path).

5.2 OBJECTIVES

The FY94 project sought to validate the HIRADSIM model, and to demonstrate the model's effectiveness on a workstation platform. These demonstrations would realize the advances made in radar sensor data fusion and environmental modeling in the FY93 program. FY94 work focused on practical applications of HIRADSIM and included comprehensive tests, evaluations, and demonstrations for qualified technical observers.

The various objectives under FY94 are detailed as follows:

1. Enhance the sea-state model fidelity and extend its accuracy for sea spikes and foam (droplets, spray, etc.).
2. Investigate techniques to reduce computation time on the model.
3. Perform additional development and refinement of the Graphical User Interface (GUI).

4. Extend the single pulse radar modeling technology for complex maritime targets.
5. Investigate methods for improving the sea state induced target motion aspects of the model.
6. Enhance user documentation.
7. Validate and proof the model.

5.3 PROJECT ENVIRONMENT

Computer modeling was conducted in GTII offices in Honolulu. Submarine periscope tests were conducted at the Pacific Missile Range Facility (PMRF) on Kauai, Hawaii, for NRaD of San Diego.

5.4 METHODOLOGY AND RESULTS

The Hawaii Radar Simulator (HIRADSIM) is a Time Domain simulator of the single pulse performance of a radar irradiating a small target in a varying sea state. The HIRADSIM program models a single electromagnetic pulse irradiated from a single source. Three target types are described in the model: 1) Submarine Periscope, 2) Zodiac (Rubber Inflatable Boat), and 3) Small Boat. Figure 5.1 is an example of the sea state model against a submarine periscope. Figure 5.2 depicts a sample of HIRADSIM output when the target is a small boat.

Each pulse transmitted by the radar is processed by several sub-models that simulate real-world conditions. The transmitter model simulates the conditions of the radar transmitter. The environment model addresses factors such as rain and atmospheric conditions. Each individual segment of the radiated pulse is ray traced for up to "n" reflections from various surfaces including the target and the ocean surface. The sea-state model depicts the interaction of the ocean waves with the radar signal. All possible signal returns (segments whose rays reflect back toward the radar antenna) are summed through a "measurement plane" which appears as a window to both the target and the radar receiver. Energy within the measurement plane contributes to the final signal to be received at the radar receiver. It includes all noise and clutter generated by the target reflections and the interactions of the waves and wavelets.

Thus, the model presents a unique single pulse response to a reflected radar signal. This information will aid the radar designer or system integrator. Significant insights can be gained to predict performance of the radar in complex conditions, or to develop new signal processing schemes.

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Figure 5.1 Submarine Periscope as modeled by the HIRADSIM sea state model

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Figure 5.2 HIRADSIM output when the target is a small boat

GTII demonstrated a tracker created with HIRADSIM to NRaD, Code 531, and the Mobile Inshore Undersea Warfare (MIUW) associate program manager. The HIRADSIM model was used to demonstrate the three types of available targets: Submarine Periscope, Zodiac, and the Small Boat. GTII led periscope detection trials at PMRF on Kauai during December 1994 as part of a demonstration for NRaD. The system successfully tracked all targets of interest.

5.5 PRODUCTS

5.5.1 Commercial Products

One product is the ship's mast detection system (SMD). CEA and GTII sold three radar trackers ($350,000 each) to the U.S. Navy as a result of this work. GTII continues to market this product. GTII seeks to develop a commercial workstation simulator for the study of general ocean surveillance radar scenarios.

5.5.2 Papers, Patents, and Disclosures

There were no papers, patents, or invention disclosures reported from this project. CEA Technologies contributed intellectual property and proprietary techniques to enable the project. CEA provided the fundamental target-model descriptions like the complex computer-aided description of a submarine periscope mast. CEA also provided the finite-difference model of the electromagnetic propagation paths to the submarine mast. This base was expanded during the course of the development into a comprehensive and unique simulator system.

5.6 IMPACT

5.6.1 Job Creation

This contract supported two full-time positions: a computer programmer in the San Diego office of CEA, and an engineer/project manager in Honolulu. The latter position was maintained in Hawaii by winning other funding for related projects.

5.6.2 Business Development

CEA Technologies Pty Ltd. continued work on HIRADSIM after the completion of the CEROS funding. CEA improved the Surface Ship Periscope Detection System for NRad on a request from OPNAV N86, and demonstrated it during RIMPAC-96 onboard the HMAS Sydney. GTII seeks other applications for HIRADSIM including periscope detection.

5.6.3 Residual Benefits to Hawaii

Two years after completion of the CEROS funding, Gateway Technologies International, Inc. and CEA Technologies Pty Ltd. continue to operate their offices in Honolulu to pursue additional modeling and support efforts with the U.S. Navy. GTII and CEA contributed about seven man-months of their own resources to conduct trials at NRaD. A pro bono copy of the system was placed on the SLICE ship built by Pacific Marine.

5.6.4 Principal Investigator/Company Opinion

The flexibility and cooperation shown by CEROS allowed GTII to achieve a very complex project on a tight budget (could have cost $1M if done by a larger engineering firm). The CEROS management approach provided a critical environment of success. Also, CEROS is willing to take technical risks even for projects that may not have a clear marketplace. The drawback of the program is that it does not have enough money to be spread around the many disserving projects in the Pacific Basin.

5.6.5 Impact on Principal Investigator/Company

CEROS provided critical funding to this project. The company benefited from the image and status of working with DARPA and the State of Hawaii. This gives credibility to the company. This credibility helped GTII to approach the U.S. Coast Guard on related projects in 1999.

5.7 TRANSITION

Based on HIRADSIM, CEA built a retrospective time domain processor. This periscope tracker is used by NRaD on the M.V. Acoustic Explorer, the U.S.S. Coronado, and on SLICE. The Royal Australian Navy consulted with GTII about purchasing several HIRADSIM simulators for use as advanced radar trainers. HIRADSIM was used to develop an improved Surface Ship Periscope Detection System (SSPDR) for NRaD. Tests of the SSPDR and the ship's mast detection system during RIMPAC-96 were very successful.

6.0 Extended-Source Apparent Motion (E-SAM) Lighted Signals for Protection of the Marine Environment

ABSTRACT

Innovations Hawaii, Inc. built and tested a pre-production prototype range light system based on the Extended-Source Apparent Motion (E-SAM) principle. E-SAM features a vertically-oriented array of sequentially operated optical flashtubes mounted on a central support tower (two towers for a range light system). When the lights are flashed in sequence they look like a moving light to a human observer, a phenomenon called Apparent Motion. This makes the light extremely conspicuous to the observer, particularly in the peripheral vision field.

Field tests conducted by Innovations Hawaii with experienced mariners as human observers at the entrance to Honolulu Harbor demonstrated that the E-SAM system is highly conspicuous, even against dense background shore lighting. Innovation Hawaii's use of flashtubes in the E-SAM also demonstrated a superior technological advance over the incandescent bulbs used by the Coast Guard in the majority of aids to navigation.

In this follow-on project also supported in FY93, Innovations Hawaii improved the design, assembled a pre-production working model, and tested it in the field. The E-SAM system's superior conspicuity was clearly demonstrated in the tests. Although the Coast Guard has professed no intention to pursue development of extended source light systems, Innovations Hawaii presented plans to discuss their specific results with Coast Guard technical representatives with a goal of further demonstrations of the E-SAM system. Innovations Hawaii provided a complete project summary to the Coast Guard R&D Center, Gorton, CT and the Coast Guard Office of Engineering in Washington, DC. There are several DoD applications for E-SAM technology, including mobile range or marking systems, mine field marking or navigation aids, and troop guidance on land. A provisional patent is being maintained.

Contractor: Innovations Hawaii, Inc.
P.O. Box 17097
Honolulu, HI 96817
phone: 808-847-4732

Subcontractor: none

Principal Investigator: Mr. Dennis Ruediger

Contract Number:	Contract Amount:	Funding Year
38195	$177,180	FY94

Start Date:	Completion Date:
November 1994	January 1997

6.1 BACKGROUND AND TECHNICAL DESCRIPTION

6.1.1 Background

With FY93 CEROS funding, Innovations Hawaii, Honolulu, Hawaii, developed a unique design for marine aids to navigation that can be easily identified against a background of confusing shoreline lighting. This chapter

summarizes the second year (FY94) of research and development of extended-source apparent motion (E-SAM) lighted signals.

Vessels navigating through channels and waterways at night are guided by a variety of lighted aids. Mariners frequently experience confusion in correctly identifying these aids against a dense background of shore lighting. The visual navigation signals must be distinctive to insure quick location and interpretation because time spent searching for a navigation signal can interfere with the demands of safely steering and operating a vessel.

6.1.2 Technical Description

The basic E-SAM design consists of a vertically oriented array of sequentially operated flashtubes mounted on a central support member. E-SAM features a vertically-oriented array of sequentially operated optical flashtubes mounted on a central support tower (two towers for a range light system). When the lights are flashed in sequence they look like a moving light to a human observer, a phenomenon called Apparent Motion. This makes the light extremely conspicuous to the observer, particularly in the peripheral vision field. As shown in Figure 6-1 of the system configuration, the sequences for Arrays I and II occur simultaneously so that the light from the lower array appears to be rising and the light from the upper array appears to be falling at the same time and rate.

6.2 OBJECTIVES

The objective of the project was to demonstrate the improvement in visibility of marine signals like navigation lights by utilizing the concept of E-SAM. The purpose of this second year of development was to design and test a pre-production prototype E-SAM system. The FY94 effort focused on developing pre-production prototypes that could be used to secure commercial or other developmental funding. Field testing has demonstrated the superior conspicuity of the E-SAM system and the principle appears ready for commercialization.

6.3 PROJECT ENVIRONMENT

The E-SAM light systems were designed and built at the contractor's facilities on Sand Island, Oahu. E-SAM testing was done in Honolulu Harbor, Hawaii (shown in figure 6-2) from onboard the Navatek I.

6.4 METHODOLOGY AND RESULTS

An understanding of psychophysics and human visual perception is key to the research conducted in this project. A moving stimulus is conspicuous when observed against a stationary background. Motion is more conspicuous in the periphery than in the central portion of an observer's field of view (FOV). Much of human perception is anticipatory and inferential based on active sampling

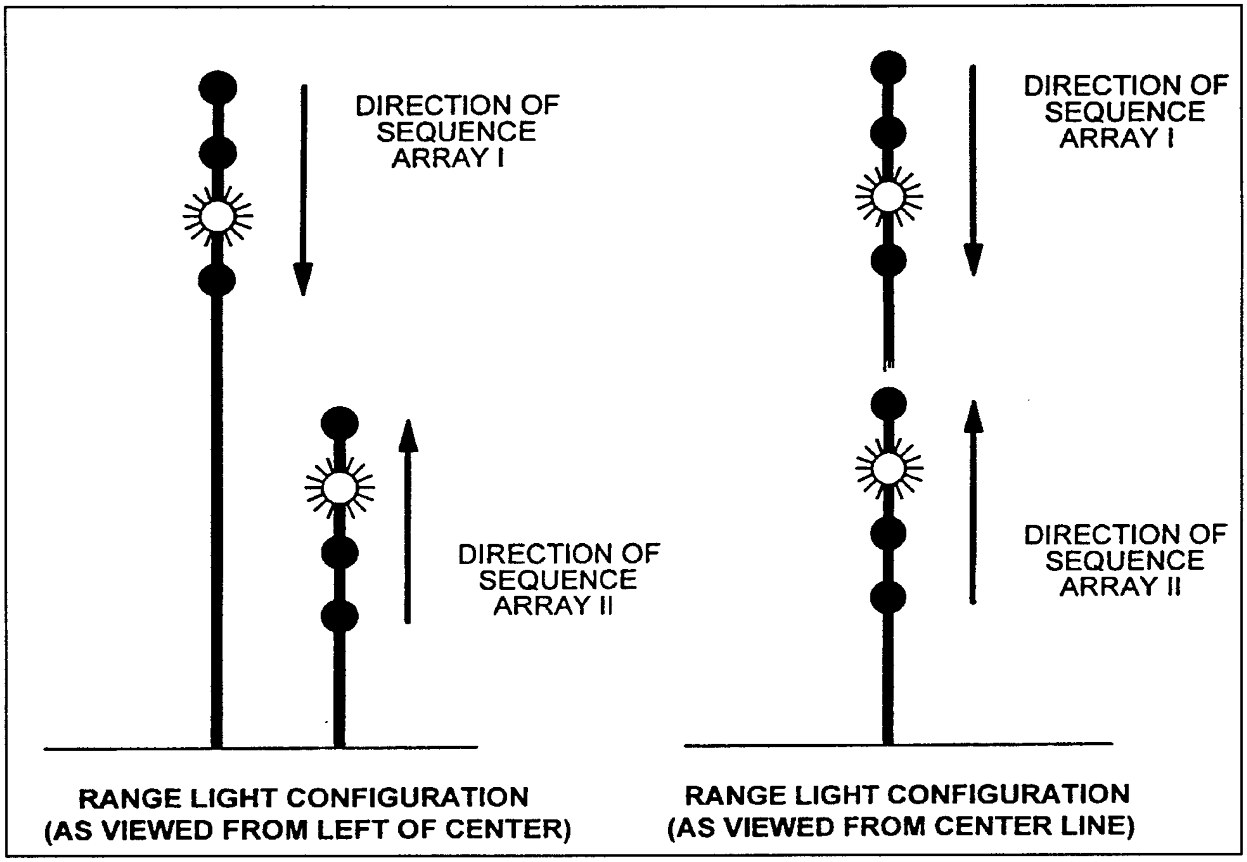


Figure 6.1 E-SAM Range Light System Configuration

clues rather than on passive reception. The human visual system constructs, implements, and fills in features of objects derived from a sampling of the physical presentation. Thus, we think a single light is moving from one location to another when we see multiple lights being flashed in sequence. An old movie marquis sign with lights flashing around the edge is a familiar example. This phenomenon is called apparent motion.

The rate and spatial separation between the flashes is crucial to the perception of motion. The variables in the perception of apparent motion are intensity, time between flashes, and angular separation of flashes. Temporal summation means that if lights are flashed in a short time (100 milliseconds), our eyes perceive a single flash with double the energy (brightness). Spatial summation is a spatial analogy to temporal summation. Spatial summation also adds the energy from each of the flash tubes, resulting in the perception of a

brighter flash. Because of these effects, plus the ability to perceive motion, each individual flash need not be very bright. As the mariner approaches the lights, the angular separation between the flash tubes increases and the effect of spatial summation is reduced. Therefore, the angular separation of lights for the E-SAM is small—3.7-arc min. at 1 mi.

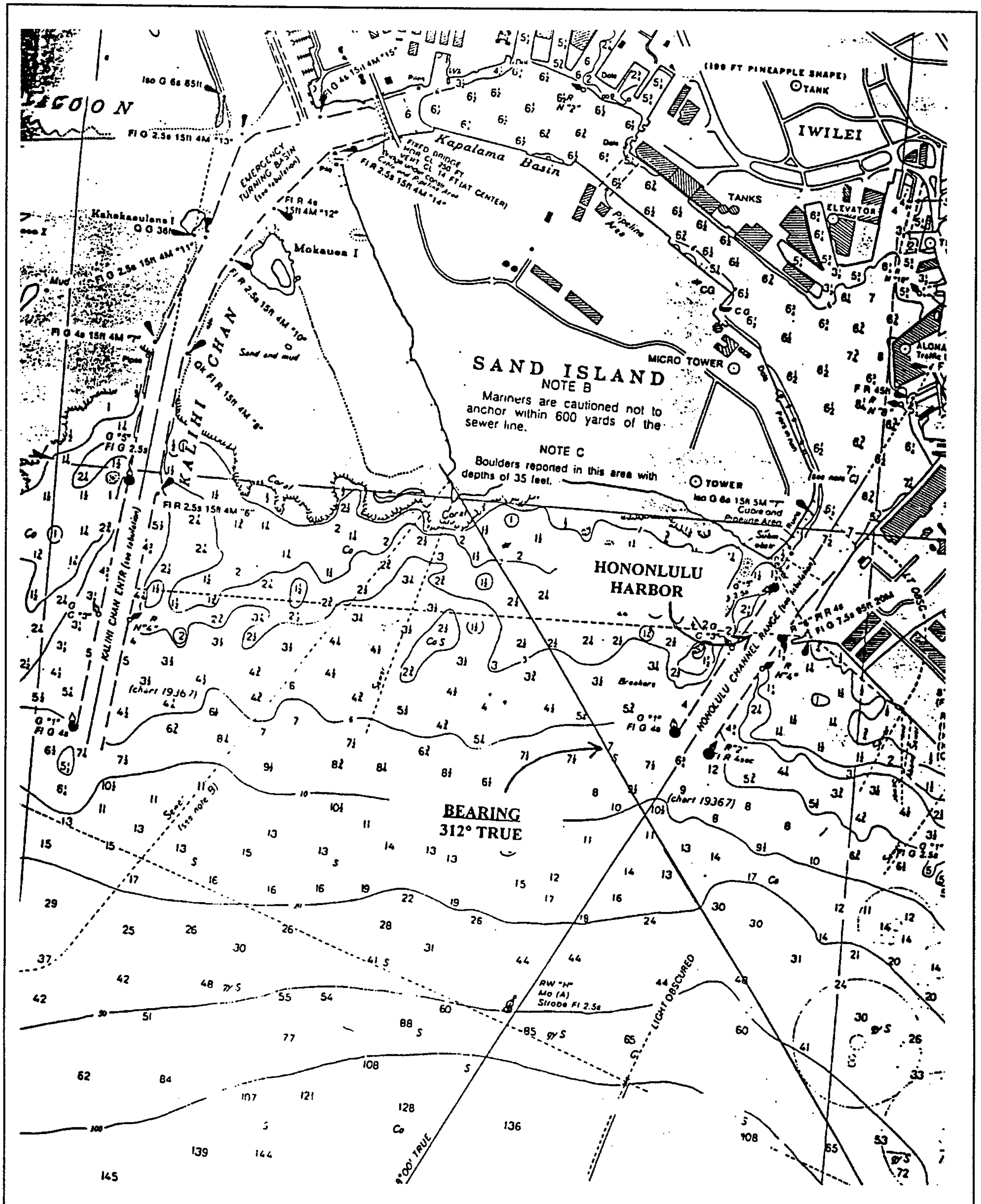


Figure 6.2 Honolulu Harbor, Hawaii

The U.S. Coast Guard (USCG) has researched conspicuous light sources including lasers, flashtubes, and extended light sources. The flashtube provides

good energy efficiency (35% compared to 1% for the incandescent bulbs currently used) and high conspicuity. However, the "flashbulb effect" could interfere with mariners' night vision because the light intensity needs to be high for conspicuity. The Innovation Hawaii E-SAM system relies on apparent motion for conspicuity so the flashtubes it uses need not be overly intense.

Innovations Hawaii designed and constructed the E-SAM range lights. Critical components that were integrated include the flashtubes, the electronic sequencer, power supply, electrical connectors, and electrical cable. The enclosures for the flashtubes and electronics were designed for water-tight construction and mounting. During this second year of the project, researchers modified the E-SAM control system to use more COTS components. The housing measures 15 in. long, 8 3/8 in. wide, and 4 3/8 in. high. The researchers also designed and built a range light test tower to support the range lights (see Figure 6-3). Figure 6-4 shows the Range Light Layout.

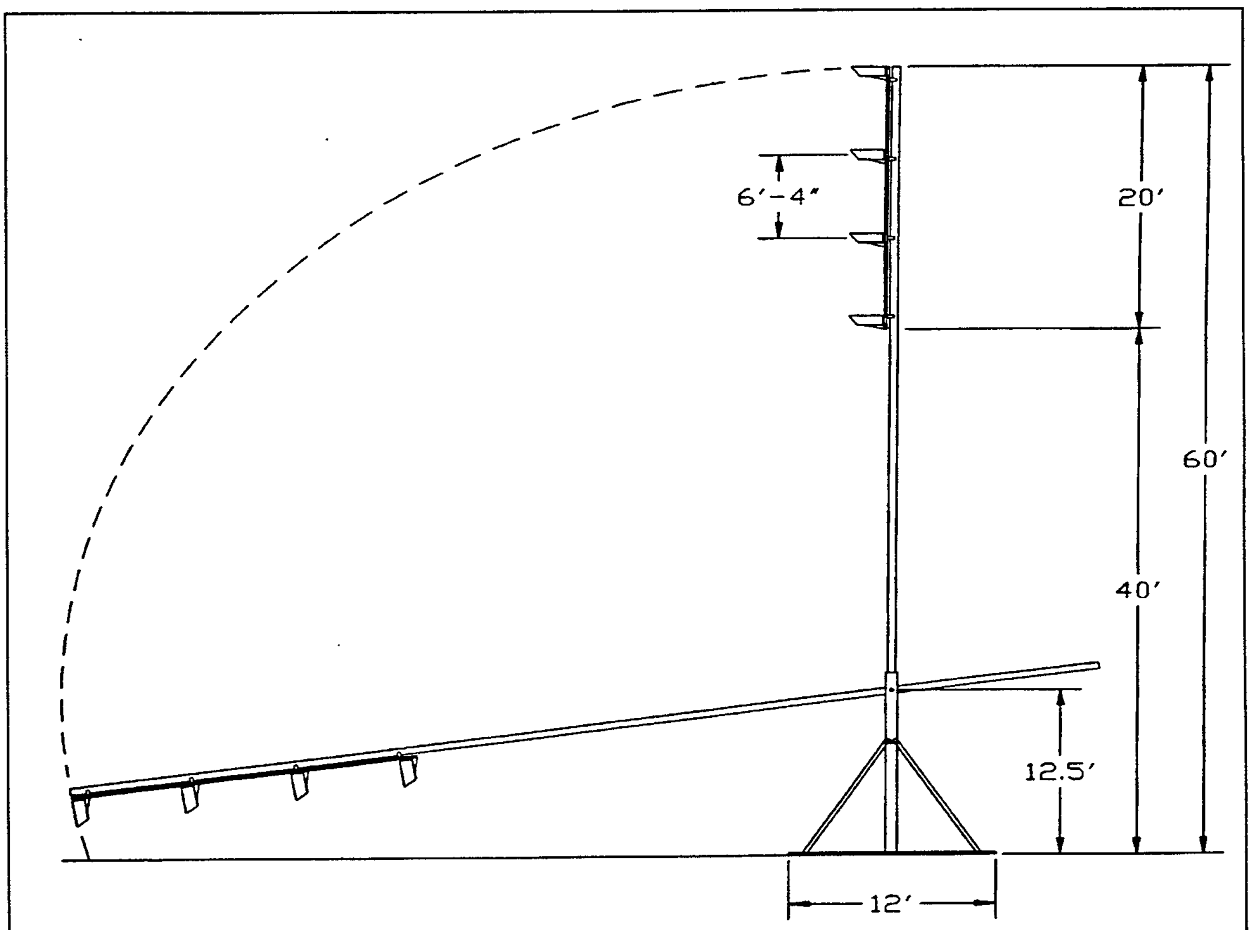


Figure 6.3 Range Light Test Tower

No standard method exists for rating the visibility of visual signals. For this project, Innovations Hawaii developed a method using reaction time: Sequence A cycles were repeated a specific number of times at 1-sec intervals. For instance,

if the test consists of 10 sequences but the observer sees only the last 7, the reaction time is 3 sec. The observers were told that the signal will begin flashing within the next minute, given the signal characteristics but not the location, then asked to count and record the number of flashes seen. Dr. Marc Mandler of the USCG R&D center was consulted and he approved of this testing method.

The field test was conducted on the evening of November 21, 1996 onboard the Navatek 1. Weather conditions were clear to partly cloudy. The moon was ¾ full and the visibility was good. The test site was located in Sand Island Park and the line of sight for observers was directly in line with the Matson container facility, a source of extremely bright and dense background light. Height of eye above sea level was 25 ft. and the average observation distance was 2.5 mi.

A series of three tests was conducted with three observers (a Honolulu Harbor Pilot, a USCG Officer, and a UH researcher). In the first test, observers located two red point-source range lights similar to USCG range lights currently in use. The observers averaged from 2 to 4 seconds to locate the point source lights. In the second test, observers located the E-SAM range light by Innovations Hawaii. Over the eight trials, the observers often located the E-SAM lights immediately and never took more than 2 seconds to see them. The final test consisted of a combination of E-SAM and steady-on point-source range lights. All three observers located the combination lights immediately on every one of the eight trials.

In summary, the second year of development showed that the system is exceedingly visible even against a dense background of shore lighting.

6.5 PRODUCTS

6.5.1 Commercial Products

A working prototype E-SAM navigation light was produced, however it was not fully commercialized during the project nor in the following years.

6.5.2 Papers, Patents, and Disclosures

No papers were published on this work. The Principal Investigator (P.I.) filed provisional patent #60/095,447 "Lighting System for Directional Guidance" with the US Patent Office and has renewed this patent each year (a provisional patent expires after one year). He will file a full patent application when he finds commercial interest in the system.

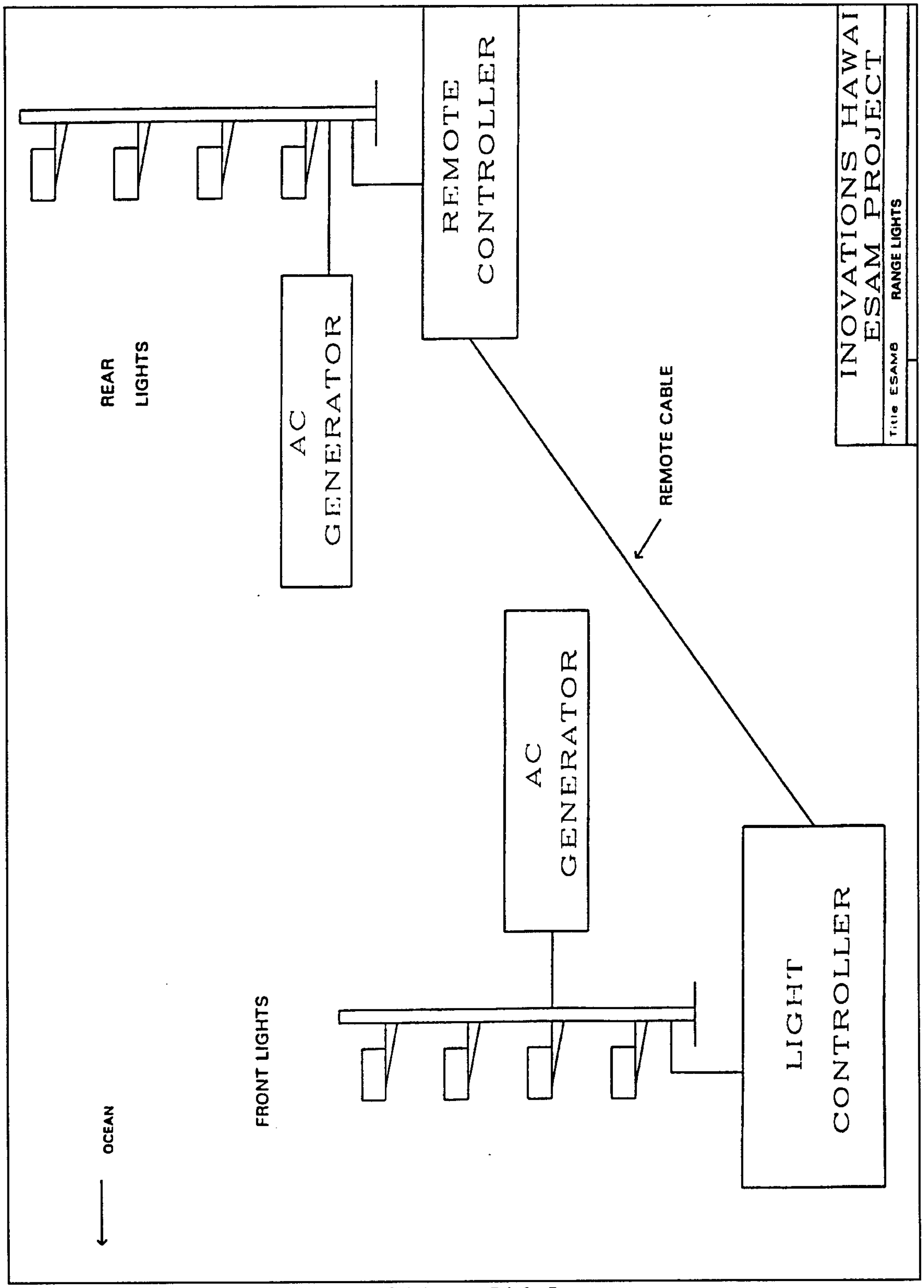


Figure 6.4 Range Light Layout

6.6 IMPACT

6.6.1 Job Creation

This project supported the P.I. full-time and two consultants half-time. The P.I. continues to work on this project despite the lack of funding.

6.6.2 Business Development

The working pre-production model is a necessary visual tool for commercialization. Although the P.I. has not found follow-on funding, at the time of this writing he continues to pursue his dream of the USCG adopting his light system.

6.6.3 Residual Benefits to Hawaii

Most of the money spent as a result of this contract was in Hawaii on consultants, materials for construction, and operating expenses.

6.6.4 Principal Investigator/Company Opinion

The principal investigator suggests that some type of up-to-date database of qualified, competent, professional consultants; (e.g., in optics and electrical and mechanical engineering), technicians, and secretarial and support staff be created and made available to grant recipients. Additional consultants could be made available at CEROS' expense to assist with commercializing, marketing, and product developing. Possibly, Federal funds could be used to commercialize a product.

Also, a liaison would be helpful to work with grant recipients to help find appropriate agency contacts and to make introductions of behalf of the recipients. Such a process could benefit both grant recipients and government agencies that might be looking for technologies to use and develop.

6.6.5 Impact on Principal Investigator/Company

This grant enabled the P.I. to produce a working pre-production model from a conceptual design with the purpose of improving harbor safety. The successful field testing produced experimental data that validated the concept.

6.7 TRANSITION

This project did not receive CEROS funds in the out-years, nor did it receive funds from other sources. The P.I. continues to pursue the USCG application although the USCG has little interest due to budgetary constraints. The P.I. has expressed a need for assistance with transitioning this product to a

commercial market. CEROS provided several opportunities through its Outreach and Technology Transfer programs.

7.0 Finite Element Design of Cables

ABSTRACT

Knapp Engineering, Inc, doing business as Structural Solutions, developed the first finite element-based computer-aided design tool for cables. The resulting computer-aided design program is named CableCAD®.

The CableCAD® code consists of 3 modules: a finite layer solver; a new finite element solver; and graphical pre- and post-processors. The CableCAD® program was written for personal computers that use either the Microsoft Windows 95 or Windows NT operating systems. The CableCAD® preprocessor was written to simplify creation of finite element cable models. The principal feature of the preprocessor is an interactive graphical database that provides libraries of wire geometries and user-defined components. The graphical environment accelerates the modeling process and improves the accuracy of results. The CableCAD® post-processor produces plots of cable reactions and deformations that provide insight into cable performance and indicate potential design improvements.

Eighteen verification problems were solved with the CableCAD® program, and the CableCAD® predictions agreed well with results presented in the reference literature. The CableCAD® software is expected to advance cable design and manufacturing and prove especially useful in assessing cable performance during handling operations.

As a result of this project, finite element analysis for cable design is commercially available to the defense, scientific and commercial oceanographic cable communities. The CableCAD® software is being produced and sold from Hawaii. Structural Solutions estimates that several hundred cable and rope manufacturers and users will have immediate interest in the CableCAD® software product that was released on the market in Spring, 1999.

Contractor: Knapp Engineering, Inc., dba Structural Solutions, Inc.
98-030 Hekaha Street, Suite 20
Aiea, HI 96701
phone: 808-488-0655

Subcontractor: none

Principal Investigator: Dr. Ronald Knapp
ssi@lava.net

Contract Number:	Contract Amount:	Funding Year
41490	$145,000	FY96

Start Date:	Completion Date:
November 1996	February 1998

7.1 BACKGROUND AND TECHNICAL DESCRIPTION

7.1.1 Background

Cable industries have relied mostly on costly prototype cable test programs to verify designs for intended applications. Some simple cable modeling programs or general purpose finite element codes have been used in

the design and development cycle. Because these cable modeling programs make assumptions that limit the accuracy of analysis results, these programs are used with understandable care and some skepticism. General purpose finite element codes require substantial skill to use properly, and modeling time can represent a significant investment. The industry needs an easy to learn, fast and accurate finite element program developed specifically for modeling cables on personal computer workstations. This program will reduce design development time and cost.

The DoD and scientific community use submarine cables in oceanographic sensor and surveillance systems. The commercial use of cables has increased dramatically as new lines are laid for communication, data transport, and other applications. Cables designed with CableCAD® will benefit from the use of stress contour plots that reveal cable performance in greater detail. This information is useful for decisions that protect fragile optical fibers, reduce fatigue life, balance torque to reduce hockling, and adjust bending and stiffness to improve cable handling and deployment.

7.1.2 Technical Description

CableCAD® is a software program to design cables, wire ropes, and flexible pipe. CableCAD® brings finite element analysis to the cable industry. CableCAD® includes a layer element model, a preprocessor, a materials library, a strand library, a postprocessor, and graphical output displays. CableCAD® can convert units between U.S. customary, metric and S.I., conduct nonlinear analysis, determine wire indentation, adjust the lay angle of layers to minimize torque, test loads and bending, and show the results in color-coded plots.

7.2 OBJECTIVES

This project sought to develop a computer aided design program (CableCAD®) for the design of submarine and terrestrial cables, wire rope, and flexible pipe. CableCAD® is the first commercially available finite element design software for cables.

7.3 PROJECT ENVIRONMENT

Structural Solution engineers conducted this work in the company offices in Aiea, Hawaii.

7.4 METHODOLOGY AND RESULTS

A new finite element was derived specifically for cable constructions and was implemented as an extension of the Knapp-SAC (Stress Analysis of Cables) computer program. The resulting computer-aided design program is named CableCAD®. CableCAD® was developed using Borland's Delphi and Mircrosoft's

FORTRAN PowerStation. Both compilers are 32 bits and support both Microsoft Windows 95/98 and NT.

The major tasks were: 1) to mathematically derive cable finite elements, 2) to develop the CableCAD® geometry and material preprocessor in Microsoft Windows 95 and NT, 3) to develop a post-processor that will produce plots, and 4) to validate CableCAD® by comparison with available experimental data.

The CableCAD® code consists of 3 modules: a finite layer solver; a new finite element solver; and graphical pre- and post-processors. The new finite elements were integrated into the former Knapp-SAC code to improve accuracy and provide more realistic analytic and design models. These models allow for various nonlinearities, unsymmetrical assemblies and loads, and noncircular components such as round, rectangular and keystone wires. The CableCAD® program was written for personal computers that use either the Microsoft Windows 95/98 or Windows NT operating systems.

The CableCAD® preprocessor was written to simplify creation of finite element cable models. The principal feature of the preprocessor is an interactive graphical database that provides libraries of wire geometries and user-defined components. The graphical environment accelerates the modeling process and improves the accuracy of results. The CableCAD® post-processor produces plots of cable reactions and deformations that provide insight into cable performance and indicate potential design improvements. Lists of numerical data such as cable forces, internal stresses, and finite element deformations can be displayed or printed.

Eighteen verification problems were solved with the CableCAD® program, including fundamental strands, communication cables, a power cable, an overhead transmission line, thermal cables, a flexible pipe and wire ropes. The CableCAD predictions agreed well with results presented in reference literature. The CableCAD software is expected to advance cable design and manufacturing and prove especially useful in assessing cable performance during handling operations.

Figures 7.1, 7.2 and 7.3 show examples of some plotted CableCAD® results. Figure 7.1 shows the CableCAD® design space, Figure 7.2 shows an example of cable stress contours, and Figure 7.3 shows a CableCAD® deformation plot.

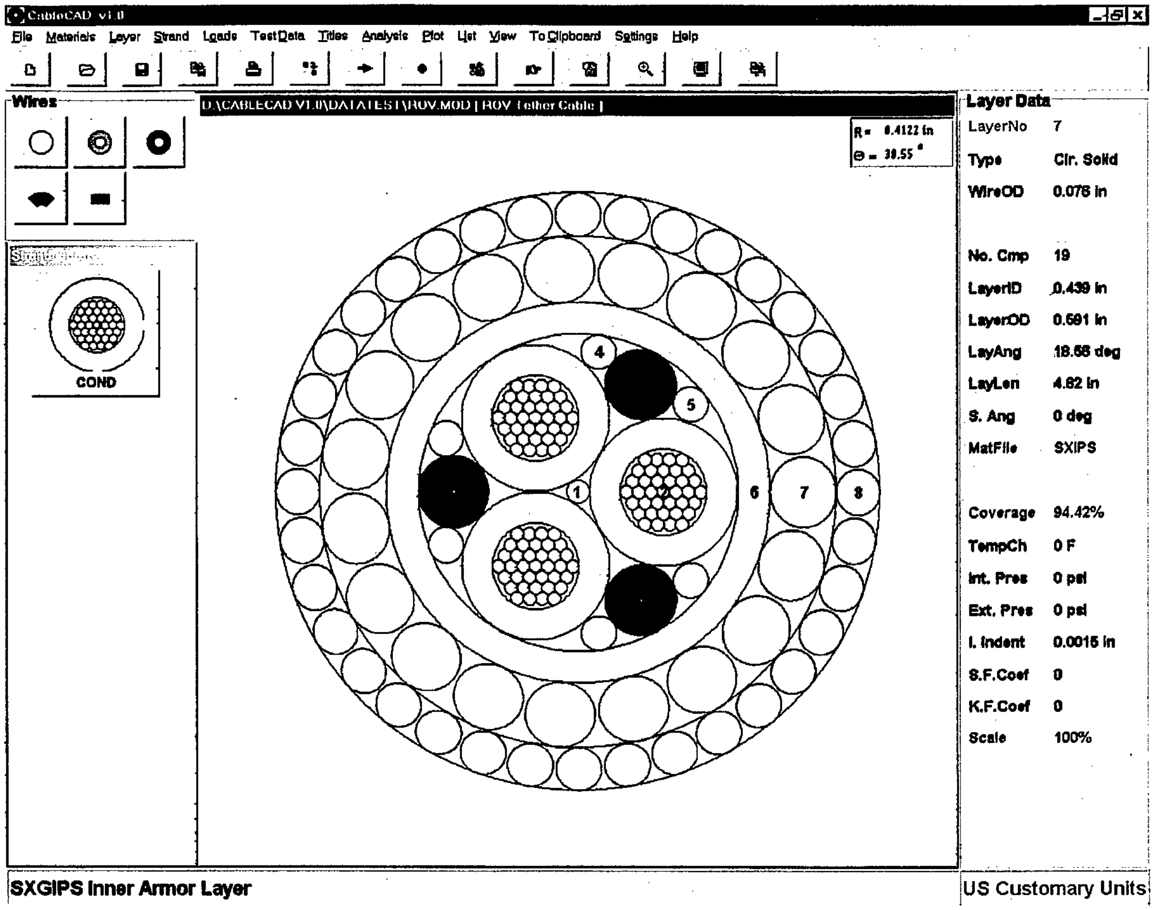


Figure 7.1 CableCAD® Design Space

7.5 PRODUCTS

7.5.1 Commercial Products

CableCAD® is the first commercially available, finite element based, computer-aided design tool for cables. It is an easy to learn, fast and accurate finite element program developed specifically for modeling cables on personal computer workstations.

7.5.2 Papers, Patents, and Disclosures

No papers have been published from this project. A free interactive demo disc is available, and a user manual was written to accompany commercial sales of the software. Knapp Engineering, Inc. secured the tradename "CableCAD®" through use and by registration with the U.S. Patent and Trademark office (trademark number 75-127174). The software code is protected as a trade secret and by copyright.

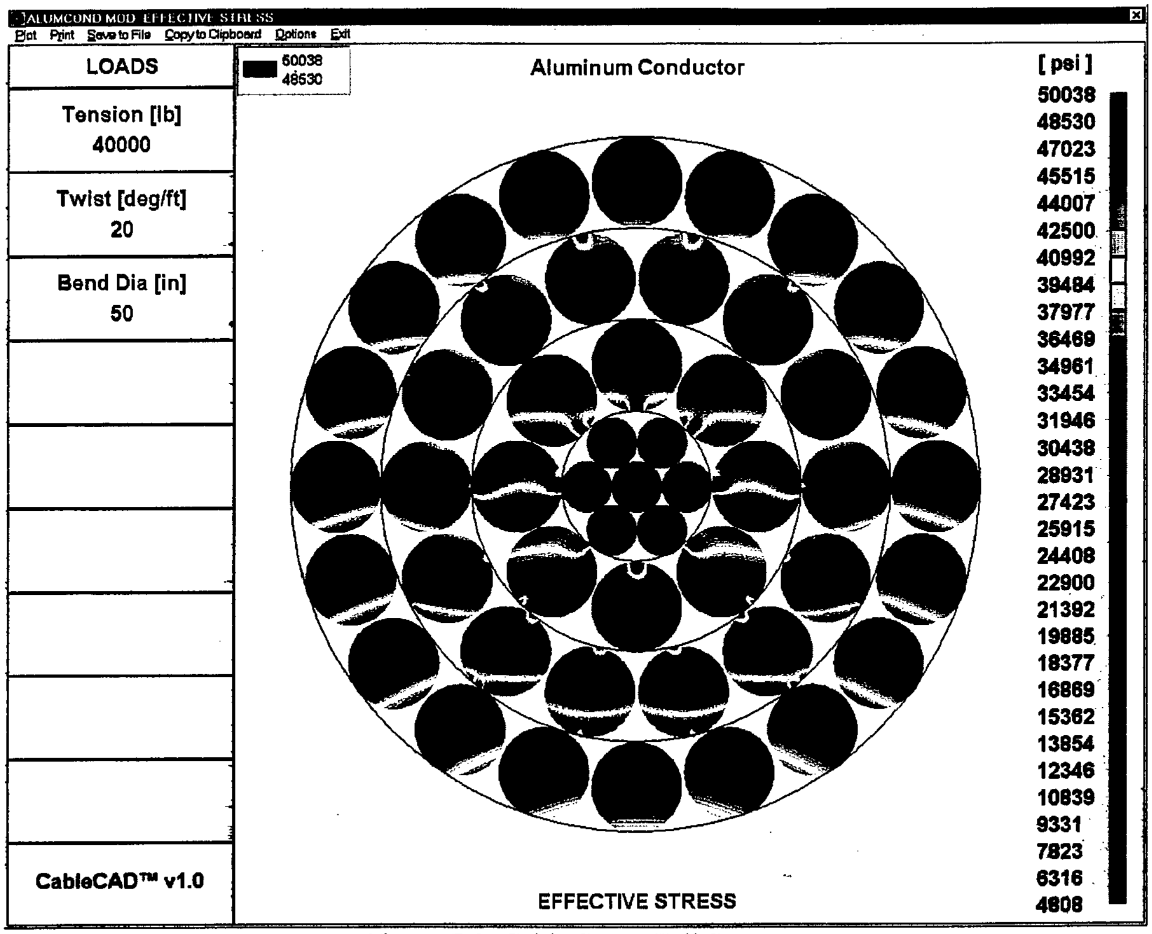


Figure 7.2 Cable Stress Full Screen

7.6 IMPACT

7.6.1 Job Creation

This job supported a programmer and a cable engineer. The programming position is permanent.

7.6.2 Business Development

In June of 1999, Knapp Engineering, Inc., dba Structural Solutions, launched commercial sales of CableCAD®. To date, three copies have been sold. Based on a market survey of the price of comparable software, a CableCAD® license is priced at $7,495. Gross sales for the first year (1999) are forecast at $150,000. As acceptance of the program improves, sale should increase in the second year.

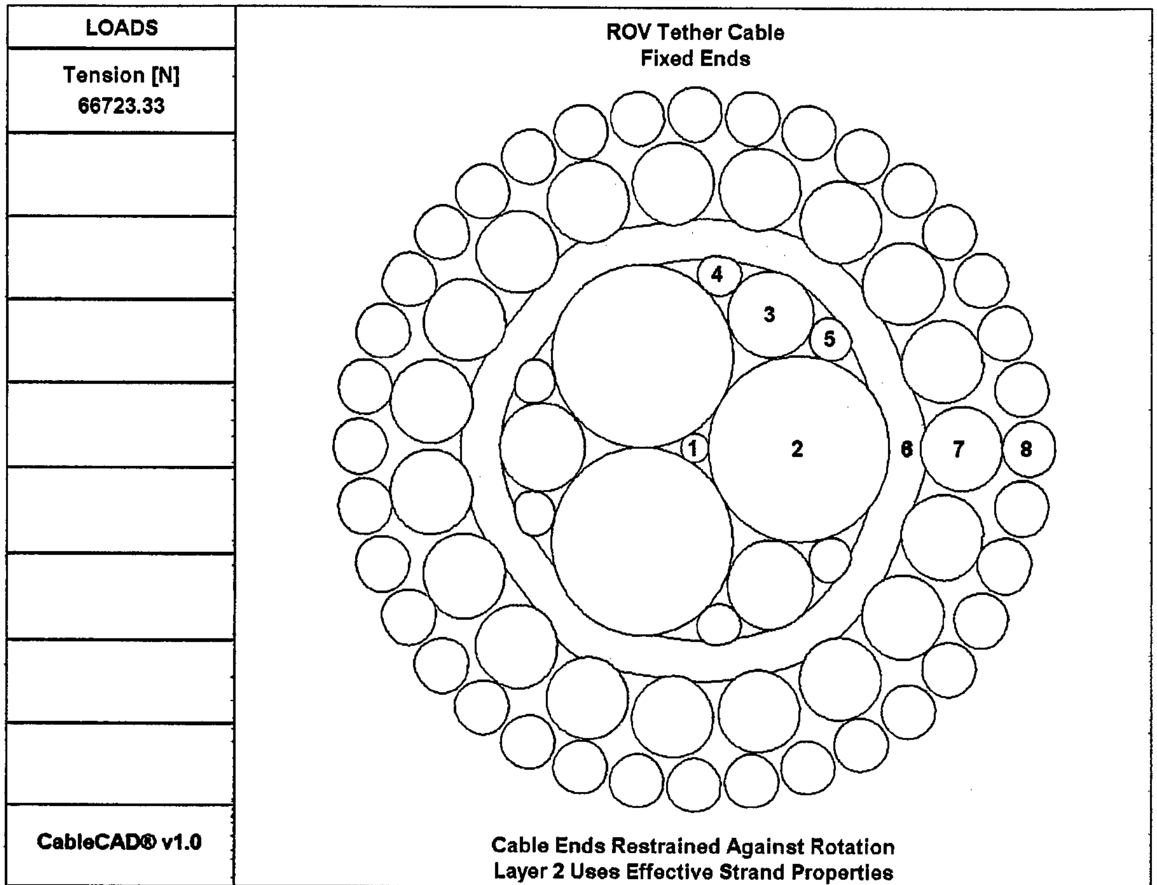


Figure 7.3 CableCAD® Deformation Plot

7.6.3 Residual Benefits to Hawaii

CableCAD® is entirely produced and sold from the State of Hawaii to the defense, scientific, and commercial oceanographic cable communities. Knapp Engineering, Inc., dba Structural Solutions, is a Hawaii owned and operated business that provides high-tech engineering and computer jobs in Hawaii. CableCAD® is the first program of its kind and it was created in Hawaii so that shows the world that cutting edge technology is being developed in Hawaii.

7.6.4 Principal Investigator/Company Opinion

Finite element analysis (FEA) for cables has been lacking, yet it is critical to the development of new cable designs. CableCAD® is the first commercially available software to perform cable FEA. Potentially, CableCAD® could contribute to improved designs of cables that perform better in service. Moreover, the FEA results could be used to plan more effective and economical cable test programs.

7.6.5 Impact on Principal Investigator/Company

CEROS funding has made it possible to add two important new features to the existing Knapp-SAC software, including a graphical user interface and finite element analysis. With these new features, demand for this cable design tool is expected to increase substantially. We anticipate that sales should be sufficient to support a programmer position and a part-time sales position.

7.7 TRANSITION

CEROS awarded $190,000 for follow-on work in FY97 to develop a companion product, CableLAB. CableLAB will allow the user to set up a cable test graphically on the computer display. Cable loads and environmental effects can be applied to the cable. By selecting regions of the cable, a CableCAD® analysis is performed and cable performance will be output for that region. It is anticipated that CableLAB will be included in the next major release of CableCAD®. Knapp Engineering, Inc. dba Structural Solutions, Inc. has applied for a U.S. registered trademark for "CableLAB."

8.0 Low-Cost Prebuckled Cylindrical Pressure Hulls

ABSTRACT

The FY94 effort built upon results of FY93 programs to further evaluate the commercial potential of polyhedrally-stiffened (prebuckled) cylindrical (PC) pressure hulls. The technical program from Knapp Engineering, Inc. (KEI) emphasized further development of the low-cost PC hull concept including detailed design, material selection, construction, and testing directly related to manufacturing and potential commercial applications. The goal of the project was to produce PC hulls that operate at 1500 foot depths and cost under $2500 each.

The result is the PC Hull™, a polyhedrally-stiffened cylindrical pressure hull. The PC Hull™ provides several advantages over traditional ring-stiffened smooth cylinders like a lower manufacturing cost, and a high buckling strength with a depth rating 2.5 times or greater than an equivalent smooth hull.

Knapp Engineering, Inc. applied computerized finite element analysis to determine the best shape for the PC Hull™. The optimal geometry depends on the properties of the composite material chosen for manufacturing. After extensive materials testing and considering both performance and cost, E-glass/epoxy was chosen. The finite element analyses selected a polyhedral geometry with an isosceles triangular facet. The shell surface is composed of six circumferential and six axial triangular facets. The designs were optimized to use the least amount of material for a hull to withstand the pressure at the design depth. The computerized studies predicted that a 0.5 inch thick polyhedral shell wall of E-glass/epoxy would withstand the hydrostatic pressure at a water depth of 1700 feet. The design effort focused on a generic AUV application with measurements of 21 inches diameter and 40 inches long.

Next, various manufacturing methods were studied for effectiveness and cost. KEI chose a filament winding process around an inner mandrel with a clamshell outer mold. Although structural imperfections occurred during prototype manufacturing, since the manufacturing process itself was also a prototype, all prototypes surpassed the computerized predictions. The prototypes were tested at Southwest Research Institute in San Antonio, Texas. When compared to an equivalent smooth hull, the prototype PC Hull™ operated at 2.5 times or greater depths.

Oceanit Laboratories, Inc. (Oceanit) conducted tow tank tests on a prototype to measure hydrodynamic properties of the PC Hull. The data compared well to computerized predictions run by KEI. Although the results show a 60% increase in axial drag over a comparable smooth cylinder, an external smooth fairing could be added to reduce drag.

In addition to increased pressure strength, several factors make the PC Hull™ less expensive to manufacture. Whereas the smooth cylinder must be formed accurately into a circular arc, the PC Hull™ can be formed by less critical molding techniques. Also, because the PC Hull™ is an inherently stiffened cylinder, the stiffening rings used in smooth cylindrical hulls are unnecessary.

The patented PC Hull™ has many uses. Defense applications include autonomous underwater vehicles (AUVs), torpedoes, antisubmarine warfare (ASW) target trainers, and sonobouys. Commercial applications include pressure housings for AUVs, remotely operated vehicles, submersibles, and ocean instrumentation.

A paper on the PC Hull concept was presented at the International Society of Offshore and Polar Engineering (ISOPE) Conference in Honolulu. U.S. Patent # 5,711,244 patent was awarded in January 1998, and KEI established the PC Hull trademark name through use. No commercial sales have resulted to date.

Located in Aiea, Hawaii, Knapp Engineering, Inc. is now called Structural Solutions, Inc..

DARPA GRANT NO. MDA 972-94-1-0010
FINAL TECHNICAL REPORT

Contractor: Knapp Engineering, Inc.
98-030 Hekaha Street, Suite 20
Aiea, HI 96701
phone: 808-488-0655

Principal Investigator: Dr. Ronald Knapp
ssi@lava.net

Co-Contractor: Oceanit Laboratories, Inc.
1100 Alakea Street, 31st Floor
Honolulu, HI 96813
phone: 808-531-3177

Principal Investigator: Dr. Warren Bucher

Contract Number:	Contract Amount:	Funding Year
41490 (KEI)	\$571,000	FY94
38203 (Oceanit)	\$ 91,000	FY94

Start Date:	Completion Date:
November 1994	October 1997

8.1 BACKGROUND AND TECHNICAL DESCRIPTION

8.1.1 Background

The conventional view of a buckled circular cylinder (CC) is that it is a "failed structure;" however, a buckled cylinder can be treated as a new "unfailed" structural form, possessing higher buckling strength than a comparable circular cylinder. Since the PC shell is out-of-round by design, small variations in shape do not affect buckling strength to the degree they would in a circular cylinder. Therefore, it could be possible to relax fabrication tolerances and reduce manufacturing costs. Also, special forming operations necessary to make circular cylinders are unnecessary for PC shells. Since the circular cylinder must be bent accurately into a curve, the PC shell is formed in a modular fashion from flat triangular plates or by laying up composite materials on a mold. Furthermore, since the PC shell is an inherently stiffened cylinder, stiffening rings used in circular cylindrical hulls are unnecessary thereby lowering manufacturing costs. Most structural materials, including transparent ones, can be used to construct PC hulls.

The prebuckled cylindrical (PC) pressure hull is a structural concept that offers new and promising alternatives for undersea pressure hulls. Both the Department of Defense (DoD) and commercial ocean industries have a continuing requirement for pressure hulls in underwater systems. A significant percentage of these systems operate in water depths from near surface to 2,000-

ft depths ideally suited to PC pressure hulls. Potential defense applications include autonomous underwater vehicles/unmanned underwater vehicles (AUV/UUV), torpedoes, antisubmarine warfare (ASW) target trainers, and sonabuoys. Possible commercial applications include pressure housings for AUVs, remotely operated vehicles (ROVs), submersibles, instrumentation, and other underwater systems.

Under related FY93 contracts Knapp Engineering, Inc. (KEI) and Oceanit Laboratories, Inc. (Oceanit) did preliminary designs of the PC Hull™, built prototype models, and conducted analyses for commercialization of the product.

Under the FY94 contracts covered in this chapter, KEI conducted the bulk of the work for this project. Under a small companion contract, Oceanit conducted hydrodynamic analysis and testing of the PC Hull™ prototypes and comparable circular cylinders in a tow tank. The work described in this chapter was done by KEI unless noted otherwise.

8.1.2 Technical Description

The PC Hull™ prototypes were constructed from E-glass/epoxy using a wet filament winding technique. The finite element analyses selected a polyhedral geometry with an isosceles triangular facet. The shell surface is composed of six circumferential and six axial triangular facets. Cylindrical ends were joined to the flat polyhedra by six circumferential conoid surfaces. The designs were optimized to use the least amount of material for a hull to withstand the pressure at the design depth. The computerized studies predicted that a 0.5 inch thick polyhedral shell wall of E-glass/epoxy would withstand the hydrostatic pressure to a maximum water depth of 1,700 feet. The ends were closed with flat, aluminum end caps and removable seals. Under pressure testing, the prototypes were able to withstand pressure equivalent to 1825 water depth before the hull failed due to material failure.

Figure 8.1 shows the computer-generated shape of the PC Hull™. Figures 8.2a and 8.2b show photographs of a prototype constructed during this project. The torpedo-size prototypes measured 40 inches length and 20 inches diameter.

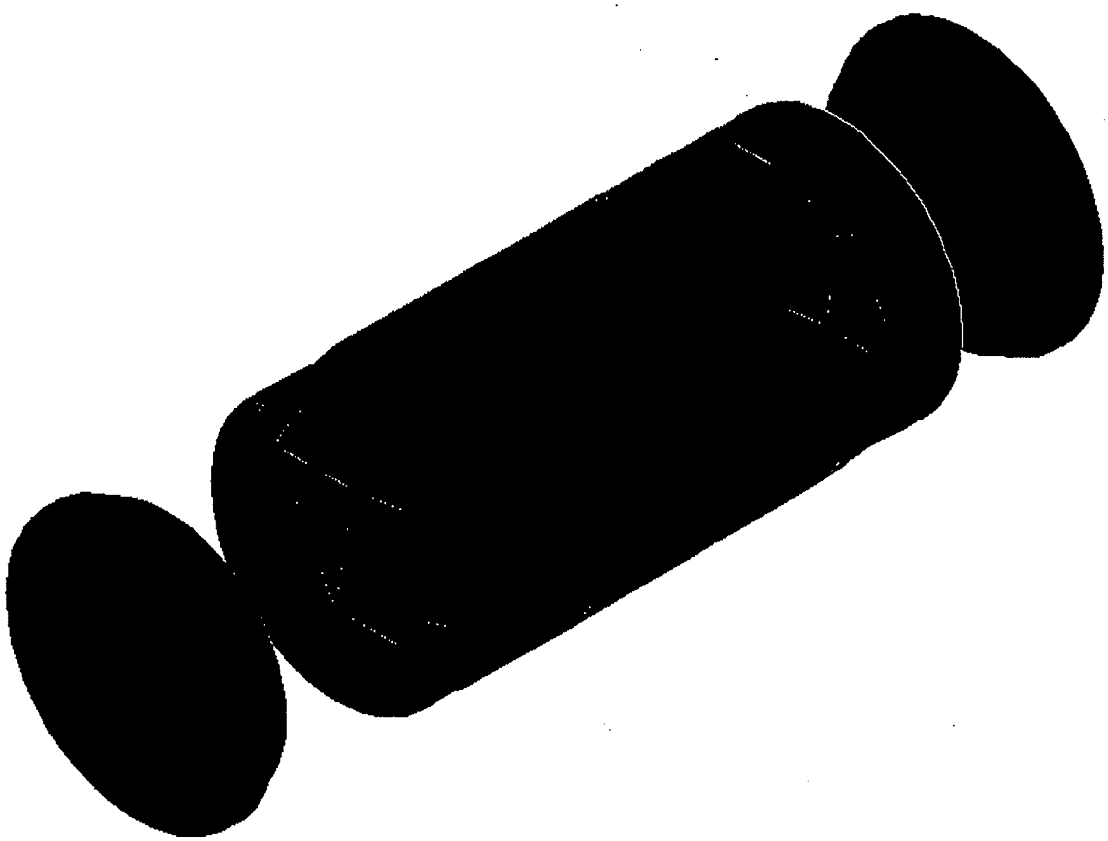


Figure 8.1 Computer-generated PC Hull

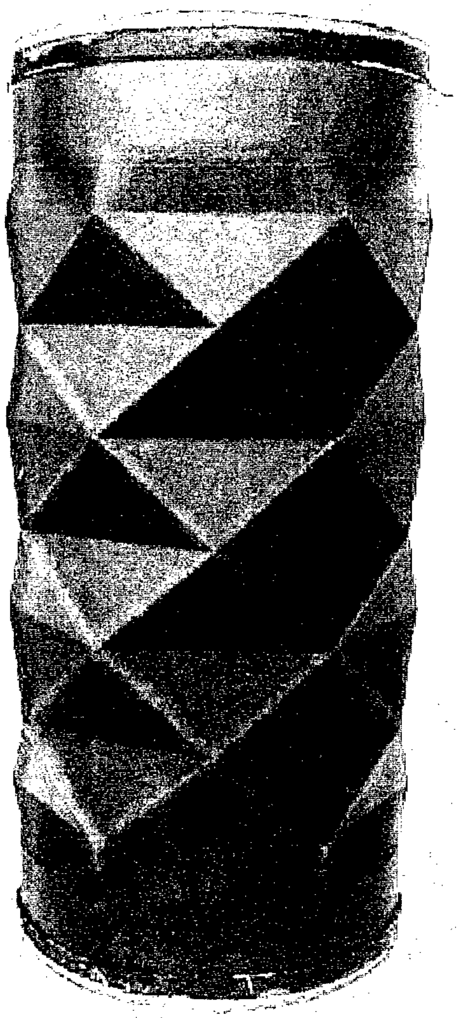


Figure 8.2a PC Hull Prototype

Figure 8.2b PC Hull Prototype

8.2 OBJECTIVES

The primary objective was to demonstrate that a PC Hull™ of a practical size can withstand the hydrostatic pressures of 1,000 to 2,000 foot water depths. The major tasks to reach the goal were to choose a hull material, conduct materials testing, optimize hull shape and design, determine manufacturing techniques, construct molds, build prototype hulls, and pressure-test hulls.

Oceanit's objective was to conduct hydrodynamic tests to analyze drag underwater.

8.3 PROJECT ENVIRONMENT

Computer analyses and engineering designs were conducted at the offices of KEI in Aiea, Hawaii. The prototype hulls were manufactured at Rocky Mountain Composite, Inc. in Provo, Utah. This manufacturer was willing to contribute to optimization of a new manufacturing process. Pressure testing of the prototype pressure hulls was conducted at Southwest Research Institute in San Antonio, Texas.

Oceanit conducted the hydrodynamic tests at the University of Hawaii J.K.K. Look Laboratory in Manoa.

8.4 METHODOLOGY AND RESULTS

This FY94 program included preliminary and final design phases, a material research effort, a manufacturing phase, and a testing phase.

KEI began with preliminary design studies using finite element analysis (FEA) to optimize the designs made during FY93 funding. Optimization primarily means determining the geometry that requires the least amount of material for a hull to reach the design depth. With 1,000 water depth as a goal, the design studies looked at shapes of end caps, removable seals for the end caps, the hull diameter and thickness, and the number of triangular facets.

For the prototypes, Knapp chose a flat end cap made of aluminum due to the lower costs. Future models could use a hemispherical end cap, especially if weight or hydrodynamics are at issue, but the hemispherical shape is expensive to manufacture.

Because the type of construction material affects the physical performance of the hull, the composite material must be chosen prior to final optimization of the design. The cost of the material and associated manufacturing costs were also considered. Several low-cost composite materials including E-glass/epoxy, E-glass/polyester, and S2-glass/epoxy underwent the following material tests: fiber volume test, void volume, composite density, interlaminar shear test, flexural test, in-plane shear test, and compression test. Considering performance and cost, E-glass/epoxy performed the best and was selected for the final design.

Once the material was chosen, Knapp optimized the design. Using FEA, they determined the depth of structural failure for different hull wall thicknesses. They chose a thickness of 0.5 inches because it can operate at 1,000 foot depth with factor of safety of 1.5. Also, this thickness will work in the filament winding process they planned for manufacturing. They modeled hulls with diameters of 11, 16, and 20 inches, and chose the 20-inch size for the manufactured prototypes. This represents the diameter suitable for deployment from a standard size submarine torpedo tube. The hull weight without end caps and 20 inches diameter was projected to be just under 100 pounds for reasonable handling and shipping. The number of facets were selected to optimize hull performance.

The manufacturing issues studied included selection of the fiber/resin system, the stacking sequence of composite plies, the molding process, and the curing schedule. Because over a dozen variables affect the mechanical properties, not all variables could be studied individually. However, the stacking

sequence is key to preventing shear failure and significantly affects the manufacturing costs. The contractor performed finite element analysis of the failure criterion to determine the best stacking sequence. The optimal stacking sequence was found to be $[\pm 45_4,(\pm 80/\pm 12_3]_s$.

For prototype manufacturing, wet filament winding was chosen because it is a machine-controlled process with very little labor involved. Also, tests showed that the dual carriage winding system does not significantly increase shearing strength, but it does reduce costs because material can be laid more rapidly. A pair of winding angles was found that yielded optimal structural performance and reduced manufacturing costs. By winding both angles simultaneously, wind time is reduced by at least half.

A manufacturing process was developed that used filament winding over an inflatable mandrel that could be collapsed into the developable PC shell surface. A hard external mold was placed over the collapsed surface and then repressurized in an autoclave to obtain both inner and outer PC shell surface definition. This technique worked reasonably well and proved to be low-cost. Although the contractor intended to manufacture six identical PC Hull™ prototypes for testing, they modified the stacking sequence after the first three prototypes were finished. However, since only seven prototypes were constructed it was difficult to optimize quality control, and all prototypes had structural defects. In spite of the imperfections, all prototypes performed significantly better (up to 2.5 times better) than an equivalent cylindrical hull under pressure testing.

Pressure tests were conducted at Southwest Research Institute in San Antonio, Texas because no suitable facilities were available in Hawaii. Two failure modes are possible, either failure of the laminate material, or shell buckling. Four PC Hull™ prototypes were externally pressurized until failure occurred. All test cylinders failed by rupture of the laminate by design; there were no buckling failures. In each case, material rupture started at the vertex of a triangular facet as predicted by finite element models. All prototypes exceeded the equivalent depth predicted by FEA. Compared to a comparable conventional cylindrical hull, the prototypes withstood pressures up to 2.5 times greater.

Oceanit Laboratories' program on PC Hulls in FY94-96 consisted of two parts: (1) at-sea pressure tests of PC hull models, (2) drag force tests on PC hull models, conducted in tow tanks at the University of Hawaii.

At-Sea Pressure Tests (August 1995). Two PC hull models were fabricated from E-Glass/Epoxy prepreg material. One was designed for a buckling depth of 18 feet in water; the second was designed for 32 feet. Both models were instrumented with strain gauges and lowered to test depth. Video and still photos were made during each test. The tests were partially successful. One model had a material problem that caused it to leak so it was unusable. The

second model was submerged until it collapsed. Collapse depth was close to that predicted.

Drag Force Tests (February - September 1995). Drag forces on PC hull models were compared with forces on equivalent circular cylinders. Models were fabricated and towed in a University of Hawaii towing tank. Models were oriented in both the longitudinal and transverse directions. The drag on the PC hulls was substantially higher than that on smooth cylinders at speeds from 1.5 to 3.25 ft/sec. The difference between drag on the PC shape and the smooth cylinder increased as speed and Reynold's Number increased. These were the first drag tests of a PC hull, and the results can be used during any future evaluation of potential applications for PC hulls.

KEI used the ANSYS FLOTRAN finite element program to predict the hydrodynamic drag characteristics of the PC Hull™. The results agree well with the tow tank data and show that the PC Hull™ with hemispherical ends would produce nearly 60% more axial drag than an equivalent circular cylinder. For stationary and low velocity ROV applications this may not be significant, but for higher velocity applications a smooth cylindrical fairing could cover the exterior surface of the PC Hull™.

This project proved that composite PC Hull™s are a new type of stiffened cylinder that can be fabricated with far less difficulty and at much less expense than composite ring-stiffened cylinders. The prototypes fabricated and tested in this program cost $2,700 (material and labor) each to manufacture (tooling costs excluded). In larger quantities, this cost is expected to fall below $2,000 per hull. An alternative manufacturing technique, resin transfer molding (RTM), was considered midway through the project but was outside the scope of the contract budget. If RTM processing could be used for these hulls, the cost could be reduced to $1,000 and the quality would improve. Development of an RTM process is recommended for commercial production.

8.5 PRODUCTS

8.5.1 Commercial Products

No commercial sales of the PC Hull™ have resulted to date. Lockheed wanted to order some for underwater instrumentation housings in 1994 but the project was still in an early development stage. Dr. Knapp is currently focused on sales of CableCAD® (see chapter 7) and development of SmartSCUBA™ (FY99, FY00). Marketing of the PC Hull™ has been delayed due to the greater profitability of these other projects.

8.5.2 Papers, Patents, and Disclosures

Significant intellectual property was created from this project. The contractor trademarked the "PC Hull™" tradename by use, and the contractor

received U.S. patent # 5,711,244, "Polyhedrally Stiffened Cylindrical (PC) Pressure Hull" in January 1998. The contractor published the following paper:

Polyhedrally-Stiffened Shells for Undersea Pressure Hulls. R. Knapp and T.T. Le. International Journal of Offshore and Polar Engineering, 8(3) pp 207-212, 1998.

8.6 IMPACT

8.6.1 Job Creation

This project supported two engineering positions. As soon as commercialization of the PC Hull begins, one engineering position will be dedicated to further development, and one part-time sales position will be created.

8.6.2 Business Development

This project has enabled the company to develop expertise in designing composite structures and finite element analysis. Expertise in these two areas has provided KEI the opportunity to develop the SmartSCUBA™ concept (CEROS funded FY99 & FY00) as well as to market finite element services in the industrial and structural engineering sectors in Hawaii. For example, our finite element expertise was used to prepare a design for a seismic retrofit of an 80-unit condominium and to design a satellite tracking pedestal.

8.6.3 Residual Benefits to Hawaii

KEI (dba Structural Solutions, Inc.) is one of a few engineering firms in Hawaii who can work with FEA software. Because KEI advertises this capability, customers have engaged its services for this expertise.

8.6.4 Principal Investigator/Company Opinion

The principal investigator clearly acknowledges that, particularly because of resistance in the engineering community to research and development of PC hulls, without CEROS' support, this project would have been impossible. CEROS' required procedures throughout the effort worked well.

8.6.5 Impact on Principal Investigator/Company

Without CEROS' financial help, KEI could not have performed the hardware development necessary to prove the concept. As a result of KEI's participation in a technology conference, Lockheed ordered eight of the cylinders; unfortunately, the order was premature because the technology was not yet ready to market. Also resulting from the conference exhibit, both the former Naval Ocean Systems Center (NOSC), Pt. Loma, California, and Panama City

Division of Naval Surface Warfare Center, Panama City, Florida, have expressed interest in the product when it is ready to market.

In addition, this research has led to the current CEROS project, SmartSCUBA™. In this project, fiber optic strain sensors are embedded in a filament-wound pressure vessel to continuously monitor its structural health (smart structure). The experience gained in the PC Hull project related to design with composite materials has been essential to addressing the technology needed to develop SmartSCUBA™.

8.7 TRANSITION

Perhaps the greatest hope of the PC hull concept is that it could advance developing composite pressure hulls. Industry has approached the design of composite hulls by adopting a structural technology that has worked very well for metal hulls. To achieve a greater buckling resistance, ring stiffeners were welded to the inner or outer surface of a circular cylinder. However, for composite hulls, finding manufacturing procedures that integrate ring stiffeners and the cylindrical hull has presented designers with major technical problems; e.g., residual molding stresses and geometrical stress concentrations where rings join the cylindrical hull. Fillets have been introduced at the ring-hull intersections to reduce stress concentrations, and special winding or bonding procedures have been attempted with limited success. These problems have contributed to the very high cost of producing composite hulls.

A new structural form is needed to further advance the development of composite hulls. The PC shell is proposed as an intrinsically stiffened shell structure that eliminates stiffening rings and thereby simplifies manufacturing processes and reduces the costs. A torpedo-shaped AUV used by the Navy and for commercial underwater surveys was identified in the FY93 program and was successfully demonstrated in the final FY94 program.

9.0 Development of a Cost-Effective GPS-Based Sensor for Measurement of Heave, Pitch, Roll and Heading on Oceanographic Platforms (Phase II)

ABSTRACT

The project developed and tested a sensor that measures roll, pitch and heading of a platform using short baseline interferometric processing of signals collected from a compact array of GPS receivers. The sensor is intended for use in oceanographic applications where precise measurements of platform rotation are required *e.g.* survey vessels or directional wave buoys. Market analysis indicated a wide potential for commercial applications on ships.

Makai Ocean Engineering, Inc. (MOE) produced a GPS attitude sensor based on results from their CEROS FY93 Core project. The rugged, reliable prototype achieved an accuracy of 0.3 degree rms. for the three attitude rotations using low-cost GPS receivers. To attain 0.3 degree resolution of roll and pitch, MOE used a 3 antenna with 2 meter spacing. A model was developed to predict the performance of various 3 antenna configurations. MOE demonstrated the prototype system on the *R.V. Moana Wave*, an oceanographic research vessel operated by the University of Hawaii. The ship was at sea about half of the three month test period.

Software upgrades produced a sensor capable of tracking up to eight GPS satellites yet able to produce accurate results from as few as three. The sensor accepts a variety of antenna configurations and can work with either a gyrocompass or fluxgate compass to further reduce false solutions. Interface improvements make the system "user friendly."

MOE and the University of Hawaii Department of Ocean Engineering used results from this project to apply for and receive a FY96 Department of Defense (Army) Small Business Technology Transfer (STTR) award entitled "Development of a GPS Directional Wave Buoy". The resulting instrument produced significantly improved directional wave spectral data. The Army invited MOE to submit a proposal for a Phase II upgrade.

Contractor: Makai Ocean Engineering, Inc.
Post Office Box 1206
Kailua, HI 96734
phone: 808-259-8871

Subcontractor
SonTek, Inc.
San Diego, CA

Principal Investigator: Dr. Joseph Van Ryzin
makai@makai.com

Contract Number: 38102

Contract Amount: $235,000

Funding Year: FY94

Start Date: December 1994

Completion Date: December 1997

9.1 BACKGROUND AND TECHNICAL DESCRIPTION

9.1.1 Background

A device that can cost-effectively and accurately measure the heave and angular orientation of a highly dynamic platform would have an immense impact on the oceanographic community. The six degrees of freedom of motion are depicted in Figure 9.1. NOAA would have immediate applications in its weather buoys that generate large amounts of oceanographic data used for weather forecasts, marine forecasts, and scientific research. Direct and indirect use of these data is immensely important to the US Navy. This product has near-term commercial applications on ships, aircraft, and any device subject to accelerations where orientation is required. Developing, manufacturing, and selling this device from Hawaii would directly benefit the state.

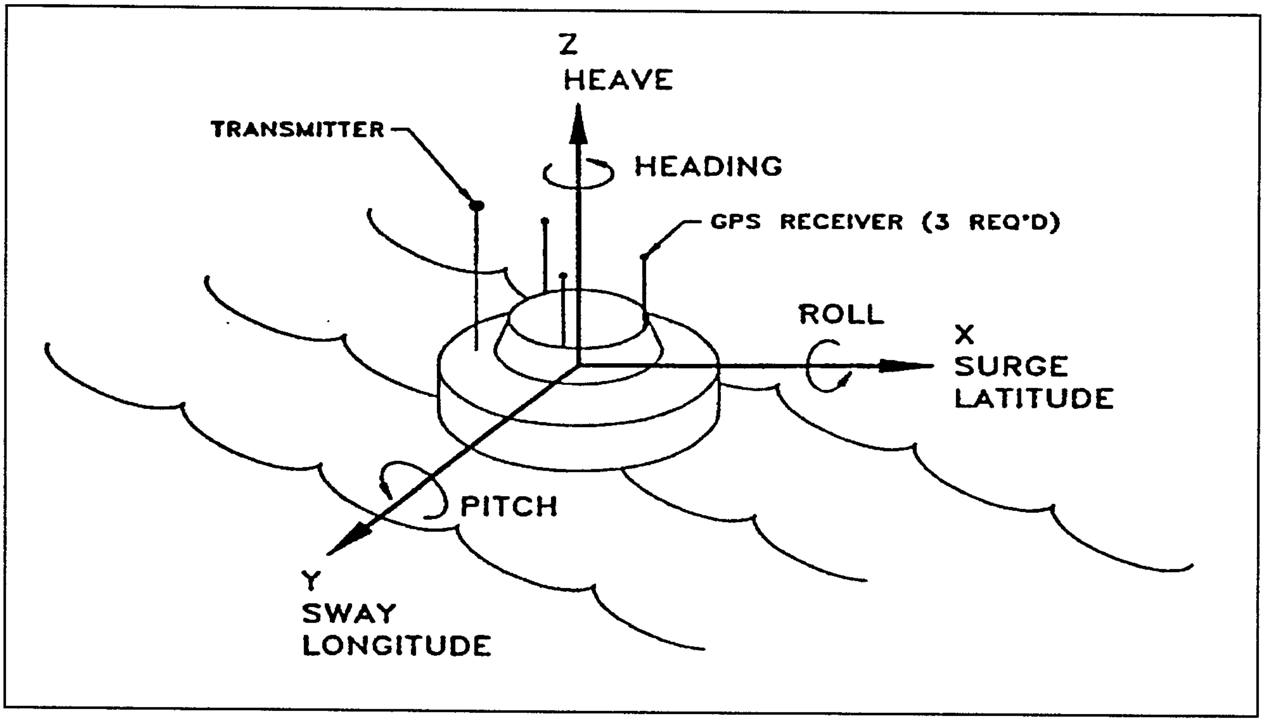


Figure 9.1 Nomenclature For The Directions Of Motions

9.1.2 Technical Description

A low-cost GPS-based attitude sensor to accurately measure pitch, roll, and heading on oceanographic platforms under highly dynamic conditions. The sensor measures the platform's motions by employing short baseline interferometric processing of carrier phases collected from a compact array of three GPS receivers. The sensor is immune to wave-induced and other dynamic accelerations that considerably degrade the accuracy of existing gyrocompasses and attitude sensors. The heading accuracy is better than the proposed accuracy of 0.3 degrees while the pitch and roll measurements meet the goal of 0.3 degrees accuracy. The standard deviation of heading is 0.1 to 0.2 degrees and that of roll and pitch is 0.2 to 0.4 degrees, depending on different GPS antenna frame arrangements (2m or 3.6m spacing).

The sensor system consists of three GPS Antennas, a Receiver Assembly to house the GPS receivers and other electronic components, a rack-mountable industrial computer, and connecting cables.

9.2 OBJECTIVES

MOE sought to design and build a low-cost GPS-based attitude sensor to accurately measure pitch, roll, and heading on oceanographic platforms under highly dynamic conditions. This system was prototyped under CEROS FY93. The FY94 work described in this chapter sought to improve both the software and hardware, and to demonstrate the sensor in the field.

9.3 PROJECT ENVIRONMENT

Makai Ocean Engineering offices are located on Makai Pier near Waimanalo on the northeast shore of Oahu.

9.4 METHODOLOGY AND RESULTS

Six technical areas to improve the attitude sensor were addressed in this second year of funding. The reason for the improvements and the method used to accomplish it are described next.

Improve the accuracy of attitude measurement. The error of the measurement of pitch and roll in Phase I was over four times the proposed accuracy. The large error indicated that the signal noise was the major problem. To achieve the proposed accuracy, either reducing the phase measurement error by 75% or increasing the antenna spacing by four times would present technical difficulties to hardware and software. This challenge was critical to the success of the project. MOE chose to upgrade the antennas to a choke-ring type to reduce multipath error, to increase the antenna spacing, to upgrade the receivers to take in eight satellites, and to upgrade the software to handle the larger antenna spacing and increased satellites.

Improve system reliability. Software that better selects satellites and handles satellite drop-out was necessary for the attitude sensor for the ship applications. The software in Phase I could only use six channels to track five satellites. However, the number of available satellites available varies from three to eight, depending on the GPS time and the geographical location of the attitude sensor. The software should be able to use any and all available satellites to achieve the best accuracy.

Due to the upgrade in receivers, eight satellites could be tracked simultaneously. The highest accuracy and reliability could be obtained if every available good satellite signal were used in each solution. However, the number of satellites varies as the platform and the satellites move. MOE developed a

method to switch the dropped-out satellites with satellites of higher elevations without error and time delay. The software was modified so it would calculate a solution for any number of available satellites from three to eight, and could switch instantly, epoch to epoch, without switching errors. The software was operated for hundreds of hours with real data. Errors were isolated and analyzed. Thus the software was slowly debugged and its overall reliability improved. Solution errors that remain are due to input noise.

Improve system flexibility. The software in Phase I worked with a triangle antenna frame with equal spacing of 1.0m. It was appropriate for an attitude meant for applications on wave buoys. To achieve the goal to develop an attitude sensor to be used on ships, the software should allow the user to customize the antenna arrangement. The challenge was that the software had to solve the unknown parameters introduced by arbitrary antenna arrangement before the normal operation.

Placing a perfectly level and accurately measured 2 meter equilateral triangle antenna array on a vessel may be an unacceptable constraint for some potential users. The software was modified so that any triangle could be used, and software was added that could survey in the antenna array on a reasonably stationary vessel before putting the attitude sensor into service. In addition, the software was expanded to work with either a gyro compass (large vessels normally have a gyro) or a fluxgate compass.

Speed up software. Increasing the spacing between the antennas would improve the accuracy of the attitude sensor. However, increasing the antenna spacing would significantly slow the software because more integer ambiguities would be involved. Because the software had to integrate with a gyrocompass instead of a fluxgate, the magnetic vector would not be available to help select the final solutions. Fast speed and correct selection would be a challenge for the new configuration.

The subroutine LIMIT was developed in Phase I to resolve the integer ambiguities. This program was further streamlined to operate faster and it was integrated with the least-square routines that identify the final solution. With these software improvements and the upgrade to a pentium computer, the processing time was safely within the time constraints allowed, even at much wider antenna spacing.

Robust Hardware. The hardware had to be rugged and highly robust under a dynamic marine environment. All three receivers, power supply, fluxgate compass, and data converters were mounted rigidly on a single printed circuit board and housed in a water resistant aluminum package. High quality connectors were used for the antenna and all other cabling was consolidated into a single system umbilical with watertight connectors. Finally, a rugged, rack-

mounted industrial computer was used for the processing. This system was run at sea for three months as part of its final testing.

User friendly Interface. A good user interface was critical to the customers' satisfaction. The early prototype had a variety of discrete software packages that were manually manipulated to demonstrate the overall feasibility. In Phase II, these packages were integrated with an informative display providing all critical information to the user in both numerical and graphical form. Figure 9.2 shows the graphic display of the MOE GPS attitude sensor.

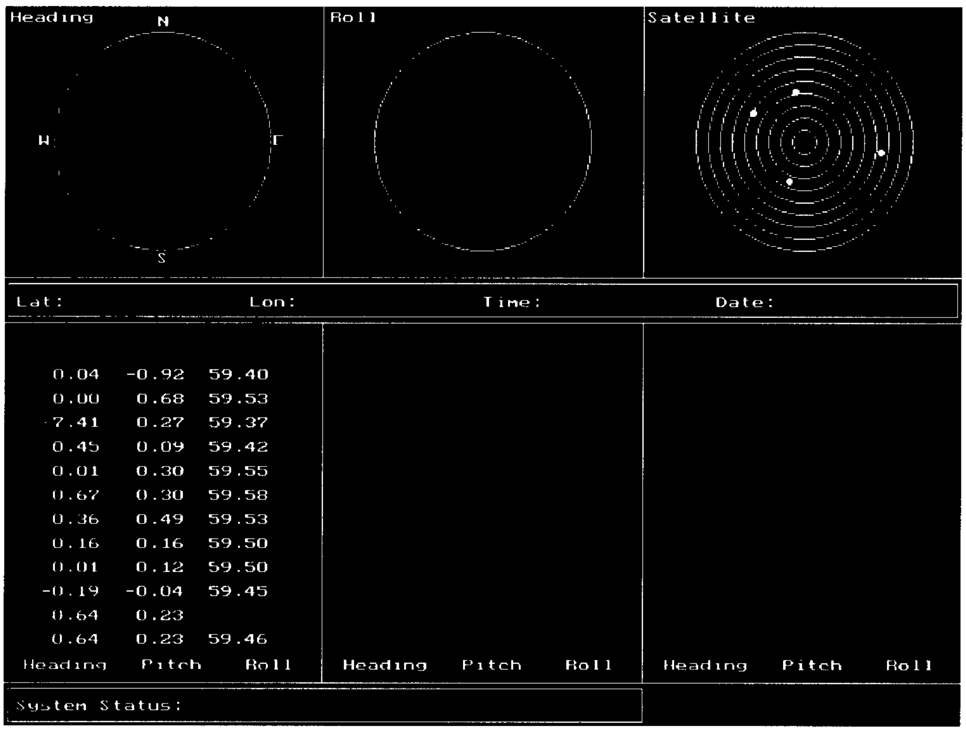


Figure 9.2 Graphic display of the Makai Ocean Engineering attitude sensor

Antenna setup routines were developed for installing the system on a vessel and these procedures were tested and further refined during field tests on the *R/V Moana Wave.* MOE demonstrated the prototype system on the *R.V. Moana Wave*, an oceanographic research vessel operated by the University of Hawaii (see Figure 9.3). The ship was at sea about half of the three month test period. The MOE motion sensor functioned as well as the ship's Gyro and a high-cost system by Ashtech in use in the ship.

Figure 9.3 Installation of the GPS antenna array on the *R.V. Moana Wave*

The GPS attitude and accelerometer results had to be interpreted in terms that show the level of improvement that can be expected in obtaining directional wave spectra from a buoy system. This second approach is a mathematical one of performing a sensitivity analyses that shows the relationship between the measured parameter (wave slope and acceleration) and the accuracy of the resultant directional wave spectra. The quality of the wave spectra was evaluated under a range of simulated sea states that emphasized the low frequency and amplitude of long period swell, a region of difficulty with current directional wave buoys.

Greatly improved performance, particularly with long period waves, can be expected if the current amplitude sensors used by the nation's weather buoys were replaced with a GPS attitude sensor. The GPS sensor would more than double the data quality. Furthermore, the GPS system should do as well with 18 second waves (a period that cannot be tracked today) as the current systems do with 7.5 second waves.

9.5 PRODUCTS

9.5.1 Commercial Products

MOE market research indicated a strong market for an accurate motion sensor in the $20,000 to 30,000 price range. However, MOE did not develop a commercial version of this invention. Parallel development, unknown to MOE, was being done by another leading motion sensor company (Ashtech) that already had significant market penetration. As a result, further commercialization was determined to be unpractical.

9.5.2 Papers, Patents, and Disclosures

No papers, patents, or invention disclosures resulted from this project.

9.6 IMPACT

9.6.1 Job Creation

The FY94 contract supported 187 days of labor at Makai spread over 6 positions ranging from 10 to 20% of each position. One technical person was hired at the beginning of Phase 1 and that level has been maintained. At the subcontractor, SonTek, the contract supported 214 days of labor spread over 5 positions ranging from 5 to 35% of each position. All jobs were high-tech software programmers, ocean engineers, and technicians.

9.6.2 Business Development

Due to the surge in its cable laying business, Makai did not pursue actively the GPS-based motion sensor as a commercial product.

9.6.3 Residual Benefits to Hawaii

This contract did not produce direct residual benefits. Although the GPS motion sensor did not produce a saleable project, CEROS funding enabled Makai to develop many successful products that allow them to compete globally in ocean engineering and cable laying.

9.6.4 Principal Investigator/Company Opinion

CEROS funds have allowed the company to perform R&D not otherwise possible. All personnel gained an abundance of information about GPS as a result of this project. CEROS's flexibility is valuable regarding necessary changes as the R&D progresses.

9.6.5 Impact on Principal Investigator/Company

The CEROS contracts stimulated significant business at Makai. CEROS is a tremendous boost for Hawaii marine companies. Without CEROS, a few businesses likely would have closed. The CEROS program allows Hawaii businesses to interact with DARPA and the commercial market and show them that Hawaii has the technical expertise to do high technology marine development with top quality.

9.7 TRANSITION

This project did not receive further CEROS funds in the out-years. MOE, with the University of Hawaii Department of Ocean Engineering, used results from this project to win a Small Business STTR contract from the U. S. Army to apply the sensor to a directional wave buoy. The resulting instrument produced significantly improved directional wave spectral data. The Army invited MOE to submit a proposal for a Phase II upgrade development project.

10.0 Design, Construction, and Operation of a 50 kW Closed Cycle OTEC Plant and Application of Results to the Design of a One Megawatt OTEC Plant

ABSTRACT

This project was competed under the ARPA Mobile Offshore Bases BAA and the award was assigned to CEROS for management. The two-phase project sought to further the development of Ocean Thermal Energy Conversion (OTEC) technology. Phase I involved advanced R&D of the design, construction and operation of a 50 kW closed-cycle (CC) OTEC plant at the Natural Energy Laboratory of Hawaii Authority facility. For Phase II, Makai Ocean Engineering would produce the conceptual design of a one megawatt CC-OTEC plant using the design and operational experience of the 50 kW plant. MOE completed design of the 50 kW CC-OTEC plant and worked with PICHTR and NELHA to construct the plant.

Heat exchanger failure occurred in July 96 because of corrosive pitting to aluminum surfaces. MOE took an aggressive analytic approach to identify the specific causes of failure. The heat exchanger modules were returned to the manufacturer for further analysis, refurbishment, and repair. MOE investigations indicated that compounds released from the nitrile spacer pads in the heat exchangers may be significant factors in the corrosive failures. MOE worked with NELHA to maximize return from investment in CC-OTEC technology. Final report for the Phase I part of the project submitted in November 1996.

MOE delivered a report on the Design Basis and Rationale for a One MegaWatt Closed Cycle OTEC Plant in February 97. This report defines major plant subsystems in a preliminary plant design and is the first deliverable of the second phase of the CEROS-contracted effort. Important design constraints and assumptions are discussed for each subsystem and for the entire, integrated plant.

MOE developed a plan to reconfigure and operate the 50 kW CC-OTEC plant at NELHA using refurbished condenser modules and submitted the plan to the CEROS Research Advisory Board in March 97. This "rescue plan" included single module tests to meet original CEROS and (D)ARPA project goals. The RAB endorsed the proposal and the NELHA Board of Directors authorized up to $200k in additional funding to support the effort. For a time, MOE suspended design and procurement actions for proposed plant modifications pending resolution of the panel refurbishment issues. Replacement heat exchanger panels were delivered to NELHA in October 1998 and PICHTR began reassembling the plant in spring 1999. As of the date of MOE's interim final report, MOE expected to gain access to the plant for its final tasks later in 1999.

Contractor: Makai Ocean Engineering, Inc.
Post Office Box 1206
Kailua, HI 96734
phone: 808-259-8871

Subcontractor: Pacific International Center for High Technology Research, Honolulu, HI

Principal Investigator: Dr. Joseph Van Ryzin
makai@makai.com

Contract Number: 38985

Contract Amount: $649,759

Funding Year FY94

Start Date: June 1995

Completion Date: June 1999 (contract closed)

10.1 BACKGROUND AND TECHNICAL DESCRIPTION

10.1.1 Background

Ocean Thermal Energy Conversion (OTEC) converts solar energy stored in the warm surface water of the world's tropical oceans into a more useable form of energy, electricity. The Natural Energy Laboratory Hawaii Authority (NELHA), established in 1974 on Keahole Point near Kailua-Kona, Hawaii, is the world's leading facility for OTEC research and development. OTEC provides an alternate to fossil fuels for electricity. While OTEC has been an alternate energy concept for over a century, commercialization has been elusive. The high cost of marine heat exchangers and the seawater supply has prevented small and intermediate size OTEC systems from being cost effective. However, these smaller scale projects are necessary to develop the technology to make OTEC economically viable. OTEC has applications for civilians living along coastlines and on islands where petroleum must be shipped in and the costs of electrical production are high. A mobile OTEC system could allow military installations to provide their own power in remote deployments. Companion products of OTEC are freshwater production from seawater, air conditioning, and on-land aquaculture with the seawater.

10.1.2 Technical Description

The OTEC plant will operate on the same basic principle as all major power plants, i.e. a liquid (usually water) is heated to steam, the steam drives turbine generators that produce electricity, and then the liquid is cooled and condensed. In traditional power plants, coal or oil is burned to heat and vaporize water, and cooling water is used to condense the water. To drive the turbine, this OTEC plant vaporizes ammonia instead of water because ammonia has a lower boiling point. The heat source is the warm, surface ocean water, and the coolant source is the cold, deep ocean water. The system is a closed cycle with respect to the ammonia so it is recycled through the process. The system is open with respect to the seawater and it remains clean enough to pass on to secondary uses like air conditioning, fresh water generation, and aquaculture.

For this OTEC demonstration, a key component is the aluminum Roll-bond heat exchangers that are used in both the heating and cooling stages. The ammonia passes through small diameter tubes within the heat exchange panels, and the seawater passes over the surface of the panels. Several pumps are crucial to the system. One pump creates a pressure drop across the turbine generator set, other pumps recirculate the ammonia, and other pumps drive the seawater flow over the heat exchangers. The system also has several safety features to contain the ammonia and to trip off the system in the case of an ammonia leak. The system is designed to prevent any release of ammonia into the surrounding area. Figure 10.1 shows a schematic of the OTEC system.

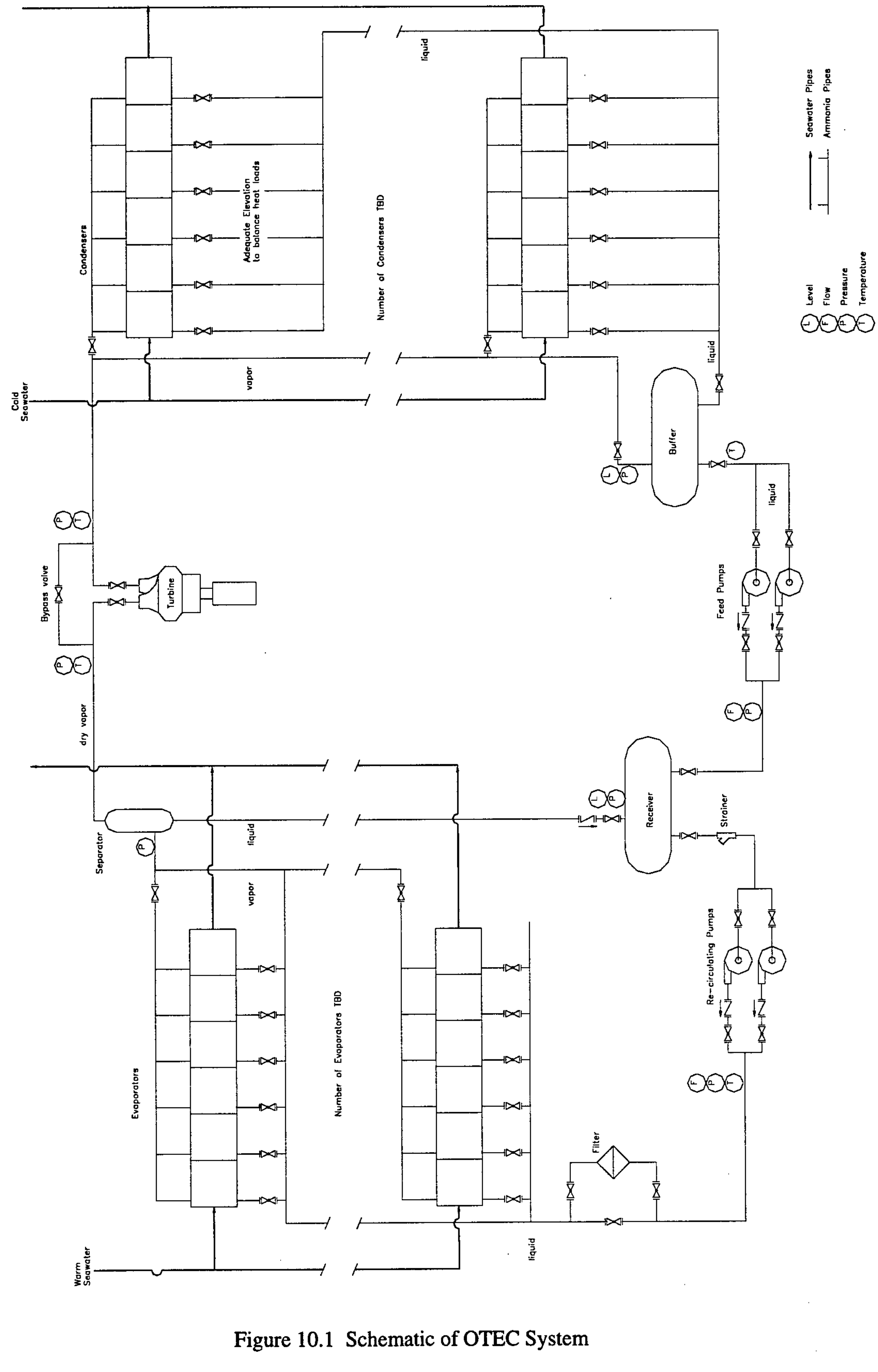


Figure 10.1 Schematic of OTEC System

10.2 OBJECTIVES

This project sought to install an experimental land-based facility using a closed cycle OTEC configuration for the testing of aluminum Roll-bond heat exchangers manufactured by ALGOODS. It also sought to generate and supply electricity to the NELHA grid. Finally, it sought to demonstrate the feasibility of mariculture projects downstream from an operating closed cycle OTEC plant by monitoring the quality of the seawater discharge. The contractor proposed to operate the CC-OTEC plant for a one-year period to perform prolonged testing of low-cost aluminum heat exchangers and other OTEC equipment.

10.3 PROJECT ENVIRONMENT

The MOE engineering offices are located on Makai Pier near Waimanalo on Oahu. The PICHTR offices are located in the Manoa Innovation Center in Honolulu. The OTEC plant is located at the Natural Energy Laboratory of Hawaii Authority on Keahole Point, outside Kailua-Kona on the island of Hawaii.

10.4 METHODOLOGY AND RESULTS

MOE had planned to design, construct, and operationally test a 50 kW OTEC pilot plant. MOE would use the results from the pilot plant to design a full-scale 1 mW plant that could operate on an economically viable commercial basis.

The design and construction of the 50 kW OTEC pilot plant began in 1994-95. In June 1996, the plant was undergoing initial operation and testing when the system failed. MOE discovered that the aluminum Roll-Bond heat exchangers had leaked due to widespread pitting corrosion after only two months of intermittent exposure to seawater. This failure dramatically shifted the course of this project as MOE became a forensic investigator to determine the cause of the failure and to recommend a new design for them. The relatively low-cost aluminum heat exchangers are a key engineering development of this project.

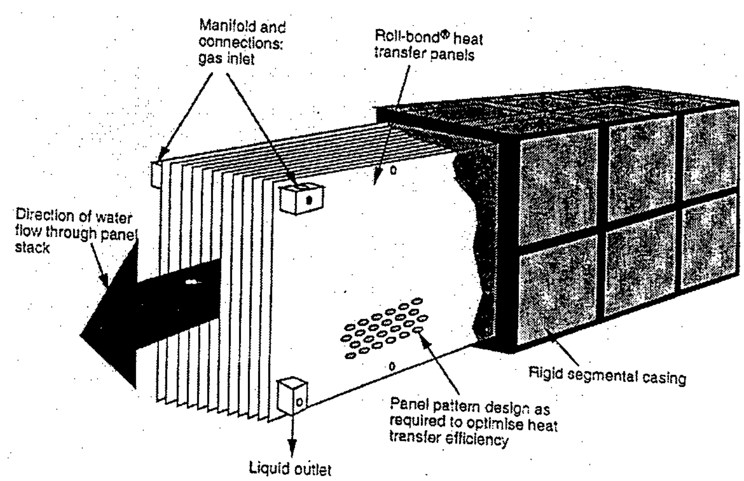


Figure 10.2 Heat Exchangers

Over a period of 1.5 years, MOE conducted tests to duplicate the operational conditions that caused the failure of the heat exchangers. MOE was able to identify the cause of the corrosion, and provided data for a solution to the problem. After receiving these data, ALGOODS, Inc. agreed to remanufacture the heat exchangers under warranty. After a difficult and lengthy remanufacturing process, the replacement units were delivered to NELHA in October 1998. While the heat exchangers were being replaced, MOE made modifications to the plant piping to allow better testing of the condenser heat exchangers.

In the spring of 1999, MOE's co-investigator, the Pacific International Center of High Technology Research (PICHTR), began reassembling the plant to resume operation and testing. Under agreements formed during the long shutdown, PICHTR will complete their testing prior to giving access to MOE. At the time of this writing, MOE has not had access to the plant. Due to administrative constraints an interim final report was provided to CEROS that will be revised and resubmitted when the testing is complete.

The lengthy interim final report from MOE is replete with engineering design plans, specifications, and research. It covers four main areas: (1) summary of the results of operation of the reconfigured 50 kW CC-OTEC plant, (2) summary of lessons learned that are pertinent to the design of the 1mW plant, (3) schematic design and thermodynamic analysis for 1 mW plant, and (4) conceptual design of a 1 mW plant with drawings, specifications, and a construction cost estimate.

10.5 PRODUCTS

10.5.1 Commercial Products

MOE can market its services for OTEC plants based on its experience on this contract. ALGOODS may develop a commercial heat exchanger based on the studies conducted by MOE under this contract.

10.5.2 Papers, Patents, and Disclosures

No invention disclosures or patents were filed as a result of this contract. No papers were published about this work.

10.6 IMPACT

10.6.1 Job Creation

Funding from this project resulted in 3.8 man years of work.

10.6.2 Business Development

MOE's involvement in this project helped lead to a contract for $85,000 to design a 1 mW closed cycle barge-mounted OTEC plant for the Indian National Institute of Ocean Technology. MOE is seeking other contracts with the U.S. Navy to plan OTEC plants for islands in the Indian Ocean and the south Pacific Ocean.

10.6.3 Residual Benefits to Hawaii

Hawaii hosts the site of cutting edge OTEC development, and MOE is a recognized world leader in several areas of ocean engineering including OTEC.

10.6.4 Principal Investigator/Company Opinion

The CEROS contracts stimulated significant business at Makai. CEROS is a tremendous boost for Hawaii marine companies. The CEROS program allows Hawaii businesses to interact with DARPA and show that Hawaii has the technical expertise to do high technology ocean engineering with top quality.

10.6.5 Impact on Principal Investigator/Company

This project allowed MOE to contribute to the technology of heat exchangers that are used in many other applications like refrigeration and heating.

10.7 TRANSITION

At the time of this writing, the contractor was waiting to gain access to the OTEC plant at NELHA to complete the next tasks of the project.

11.0 Development of an Automated Control System for Deployment of Small Diameter Cables and Towed Bodies; Loop Avoidance Control for Submarine Cables

ABSTRACT

Led by Makai, a new generation of cable control software has come on the market. This software is able to account for the integrated time history of the cable lay and to calculate things like bottom tension, slack, and the shape of the cable in the water column, especially near the bottom. The system controls vessel course and speed, cable pay-out rate, solves the linear relationship, and forecasts what action is necessary to achieve desired cable placement. One focus is to minimize errors in "cable touchdown", *i.e.* variations in the actual versus preplanned positions. The mathematical model behind this software is based on the "caternary" solution, or zero stiffness model, where the only force in the cable is tension which (by definition) acts along the axis of the cable. Prior to this project this software did not account for twist and torque developed prior to and during the lay.

The results from this project suggest that a reasonably accurate prediction of cable loop formation under specific lay conditions can be provided. Furthermore the inclusion of stiffness into the cable model opens up a new area of market in the pipeline deployment field. Relatively simple measurements on cable can provide parameters that will allow prediction of cable loop formation to a reasonable degree of accuracy.

The final product is being marketed to DoD and commercial customers. When MOE sold and delivered a Cable Lay Simulator to Nippon Telephone & Telegraph in 1996, the software modifications to make the simulator more "user friendly" for NTT were applied to the CEROS effort.

Contractor: Makai Ocean Engineering, Inc.
Post Office Box 1206
Kailua, HI 96734
phone: 808-259-8871

Subcontractor:
Knapp Engineering, Inc.
98-030 Hekaha Street, Suite 20
Aiea, HI 96701
phone: 808-488-0655

Principal Investigator: Dr. Joseph Van Ryzin
makai@makai.com

Contract Number:	Contract Amount:	Funding Year
38111	$325,000	FY94
41526	$287,000	FY96

Start Date:	Completion Date:
December 1994	March 1997
December 1996	June 1999

11.1 BACKGROUND AND TECHNICAL DESCRIPTION

11.1.1 Background

In terms of cable installation practices, historically, a ship would drive a trackline and payout cable with little knowledge of the actual conditions of the lay on the bottom. Cable slack could cause loops and use more cable than was necessary, too much tension causes the cable to span irregular and rough bottom features, and subsurface currents could carry the cable significantly off the intended cable path.

Cable torque and twist problems have affected military cable operations, the oceanographic community and commercial cable installers for over a century. Armored submarine cables used for telecommunications are generally manufactured with their armor wires laid in one direction, a left-hand helix

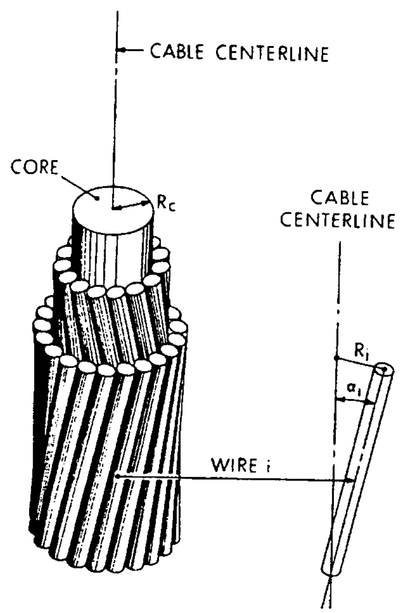


Figure 11.1 Typical armored cable

These helically-wound armor wires, when tensioned by the weight of the suspended cable during a deployment operation, create an internal torque in the cable that can cause the cable to twist and form loops during laying or retrieval. When tensioned, these loops create kinks that permanently damage the cable. Undetected loops that have not yet formed kinks are weak points that may cause damage in the future (see Figure 11.2).

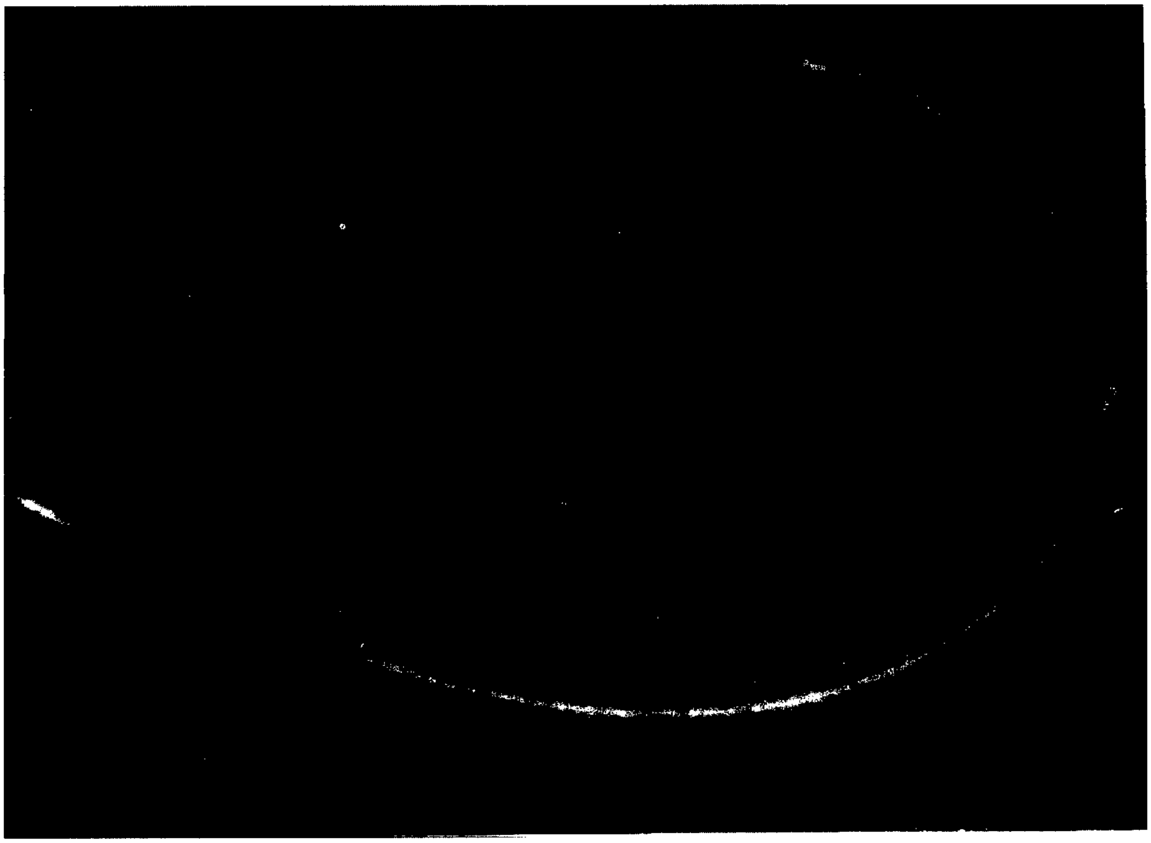


Figure 11.2 Typical cable loop laid during the 1989 Hawaii Deep Water Cable Program

Repair of a single cable link may require several costly deployment days and cause significant down time. Loops and kinks are a common problem during military and commercial cable lay operations and their avoidance is a constant concern.

Communication, computer data, and military cables are circling the globe at exponential growth rates. Although difficult to achieve, accurate, loop-free placement on the ocean floor is critical to proper cable function and interruption-free service. The DoD uses submarine cables for communications and data transfer, and for underwater acoustic systems to perform surface vessel and submarine tracking missions. The immediate need for improvement in cable laying is evidenced by a FY99 Navy SBIR topic on cable loop forming. Military applications of cable that require precise placement are driving the industry to develop better cable deployment systems. Cable deployment is the most expensive part of any submarine cable system, and small-diameter cables like fiber optics demand improved cable lay control systems.

11.1.2 Technical Description

The Cable Lay Simulator provides for detailed planning of a cable lay. The Cable Lay Monitor allows for real-time data input during the cable lay to monitor

and log the cable installation. The Integrated Cable Deployment Control System computes the proper ship course and cable payout based on actual at-sea conditions encountered during the cable installation.

11.2 OBJECTIVES

The FY94 project sought to develop and validate a computerized control system simulator for the deployment of small diameter cables. The automated submarine cable laying control system would serve DoD and commercial markets. Makai used an existing program for larger diameter cables and their in-house cable laying experience. In FY96, Makai improved its software to prevent loop-forming during a lay.

11.3 PROJECT ENVIRONMENT

Makai Ocean Engineering offices are located on Makai Pier near Waimanalo on the northeast shore of Oahu.

11.4 METHODOLOGY AND RESULTS

Cable loops are formed when critical combinations of torque, cable curvature, and bottom tension are reached. Not only do the cable characteristics and loop-formation theory need to be well understood, but a complete understanding of the cable and the dynamics of the cable lay, minute-by-minute, must be known. Only then can the risk and level of loop forming be evaluated and loop avoidance can be achieved.

The FY94 effort focused on:

- Developing algorithms necessary to automate control system operation and improve lay accuracy;
- Validating the program for small diameter ("Micro") cables; and
- Integrating the changes into an operational cable lay simulation program.

All changes to the control system and simulator were made with potential future U. S. Navy applications in mind. These Navy requirements include system use by operators with minimal training, high accuracy and reliability, and absolute cable slack control. MOE automated the control system in 3 steps by (1) developing an automated synchronization program to run software and monitor lay progress, (2) developing algorithms and automating selection of optimal ship and cable instructions, and (3) improving ocean current predictions capabilities and integrating ocean current information into the lay control suite.

The FY96 effort focused on loop avoidance and included seven tasks: (1) determine reliability of cable torque/twist characteristics; (2) integrate torque and twist accounting into cable laying models; (3) incorporate loop forming algorithms

into the cable laying model; (4) perform sensitivity analysis on loop forming prediction; (5) evaluate performance with real data; (6) cable lay measurement standards for loop formation monitoring, and (7) determine potential for loop avoidance control.

The primary factors affecting loop formation on the bottom are excess slack in the as-laid cable, twists built into the cable during manufacturing or while handling the cable on deck, transitions between two different cable types with different torsional properties or weights, laying of in-line cable bodies, especially heavy bodies, sudden changes in bathymetry, ship heave, and inability to control the ship position or cable payout rate.

MOE met the objectives of the contract and validated the resulting Integrated Control System and Cable Lay Simulator for use with Micro cables. An operational cable lay simulator incorporating all automation features was developed. MOE is continuing to develop the cable deployment control software through various commercial contracts.

Led by MOE, a new generation of cable control software has come on the market. This software is able to account for the integrated time history of the cable lay and to calculate things like bottom tension, slack, and the shape of the cable in the water column, especially near the bottom. The mathematical model behind this software is based on the "caternary" solution, or zero stiffness model, where the only force in the cable is tension which (by definition) acts along the axis of the cable. Prior to this project this software did not account for twist and torque developed prior to and during the lay.

The results from this project suggest that a reasonably accurate prediction of cable loop formation under specific lay conditions can be provided. Furthermore the inclusion of stiffness into the cable model opens up a new area of market in the pipeline deployment field. Relatively simple measurements on cable can provide parameters that will allow prediction of cable loop formation to a reasonable degree of accuracy. Figure 11.3 shows a schematic of the parameters covered by MOE's cable lay system.

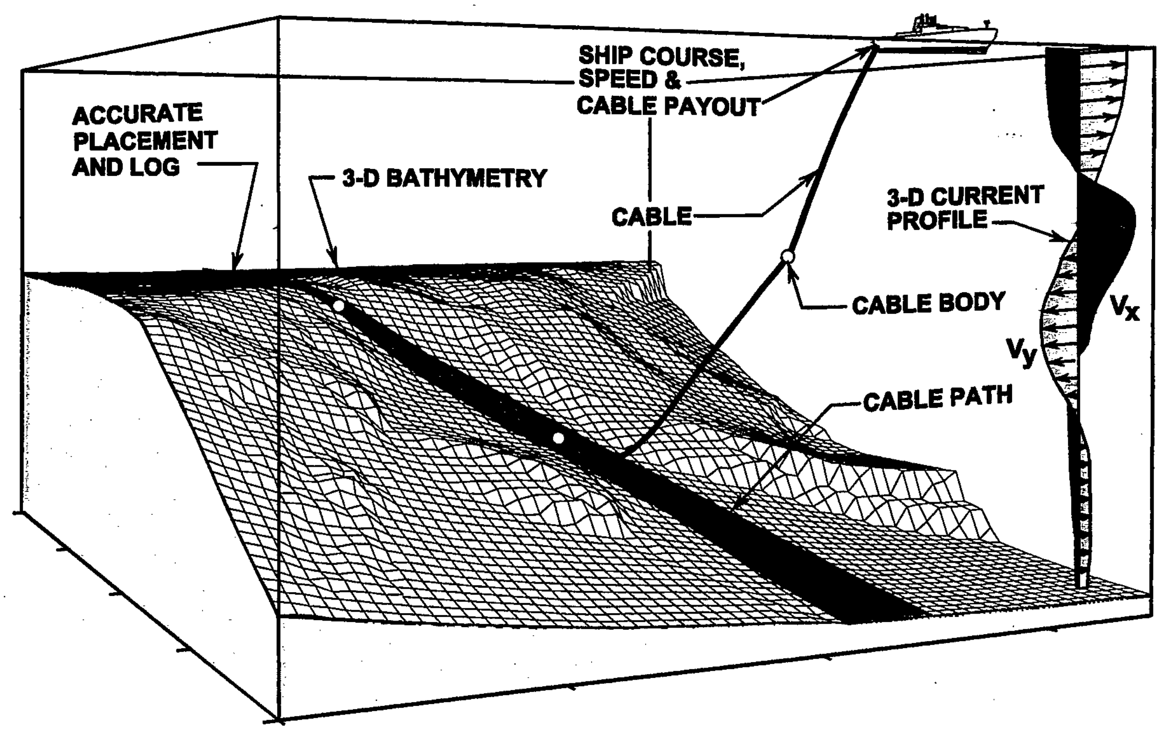


Figure 11.3 Schematic of the parameters covered by Makai's cable lay system

11.5 PRODUCTS

11.5.1 Commercial Products

As of the time of this writing, MOE has several commercial products that grew out of this project. These include cable lay services and commercial software like MakaiPlan™, and the Makai Submarine Cable Installation Software comprised of the Integrated Cable Deployment Control System (ICS), the Cable Lay Simulator (CLS), and the Cable Lay Monitor (CLM). The ICS is a complete package of software able to control actual at-sea cable deployment operations and to simulate the same operations in the office. Figure 11.4 provides a conceptual diagram of MOE's cable software tools.

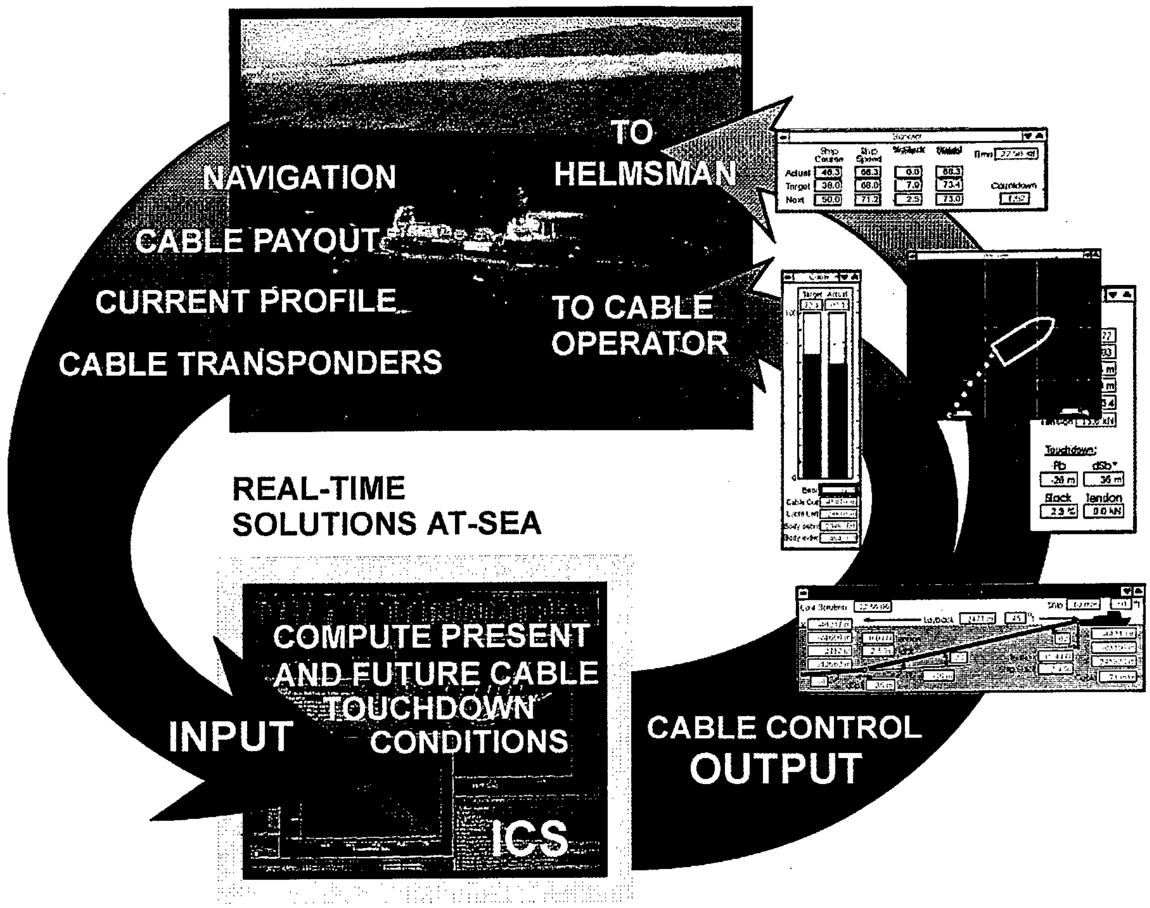


Figure 11.4 Conceptual diagram of Makai's software tools

11.5.2 Papers, Patents, and Disclosures

The software is proprietary to MOE and commercial software sales require a "key" to operate. MOE will trademark several product names to protect them and create intellectual property. There were no patents or invention disclosures from this project. The following papers were published.

The Real-time Control of Cable Seafloor Slack and Placement, The Present and Future. Joseph C. Van Ryzin, Jose M. Andres, and Stephen R. Jefferies. SubOptic '97, San Francisco, California, May 1997.

Real-time Controls Aid Seismic Survey Cable Deployment and Retrieval. J.M. Andres. Offshore, March 1998, pp. 58-62.

11.6 IMPACT

11.6.1 Job Creation

The FY94 contract supported 504 days of labor at MOE spread over 5 positions ranging from 1/6 to over half of each position. The FY96 contract

supported 396 days of labor at MOE spread over 6 positions ranging from 1/10 to ½ of the position for a year. These jobs were high-tech ocean engineers and technicians. The FY96 contract also supported a subcontracted ocean engineer for a full month. As of the time of this writing, MOE had added two engineers for pipe work and one engineer for MakaiPlan™ during calendar year 1999. These new positions grew from this contract and the new work that MOE received due to its expertise in cable laying.

11.6.2 Business Development

These state-of-the-art cable installation systems make Makai Ocean Engineering, Inc. a world leader in accurate submarine cable deployment and their business is booming. Export of this product has MOE's engineers working on contracts around the globe in commercial and military cable installations.

11.6.3 Residual Benefits to Hawaii

This project kept Hawaii in the forefront of state-of-the-art cable installation systems. This is an export product for Hawaii and the U.S.-- a technology needed worldwide.

11.6.4 Principal Investigator/Company Opinion

The CEROS contracts stimulated significant business at MOE. CEROS is a tremendous boost for Hawaii marine companies. Without CEROS, a few businesses likely would have closed. The CEROS program allows Hawaii businesses to interact with DARPA and the commercial market and show them that Hawaii has the technical expertise to do high technology marine development with top quality.

11.6.5 Impact on Principal Investigator/Company

CEROS funding enabled MOE to develop many successful products that allow them to compete globally in ocean engineering and cable laying.

11.7 TRANSITION

Makai Ocean Engineering, Inc. developed these systems with CEROS funding and corporate development funds. In August 1999 MOE began to market a commercial cable laying software called "MakaiPlan™" and had several orders waiting to be filled as soon as the program was ready for distribution. A single license was initially priced at $16,500.

12.0 Ocean Doppler Lidar

ABSTRACT

In preliminary trials at a University of Hawaii facility, Mission Research Corporation demonstrated a new way to detect underwater moving objects at long range in shallow waters. For the first time, underwater moving targets were detected with a laser radar (lidar) using their Doppler signature. MRC developed a novel Moving Target Indicator (MTI) filter that rejects ocean optical clutter so Doppler processing can be used to reject backscattered energy while passing the light scattered from moving objects.

Mission Research Corporation demonstrated the Ocean Doppler Lidar at the J.K.K. Look Laboratory Optical Test Range operated by the University of Hawaii at Kakaako Penisula, Oahu. Researchers observed unmistakable lidar signatures from an underwater moving belt target at 300 m range and 5 m depth. This initial detection of an underwater moving object with a laser achieved over 15 dB target-to-clutter ratio at shallow grazing angles. Previous tests at NRaD in 1978 achieved a 0.8 dB ratio. The results demonstrate that the Doppler filter is capable of rejecting clutter and passing the target signal, in ocean field conditions, thereby confirming the utility of the Ocean Doppler Lidar.

If verified, proven, and developed to a systems level, the Ocean Doppler Lidar concept could provide a means of long-range shipboard detection of underwater moving objects, such as torpedoes or, possibly, submarines.

Contractor: Mission Research Corporation
3625 Del Amo Blvd
Torrance, CA 90503
phone: 310-793-1630

Subcontractor: Edward K. Noda & Associates, Inc.
615 Piikoi Street, Suite 1000
Honolulu, HI 96814
phone: 808-591-8553

Principal Investigator: Dr. Jerry Butman
jbutman@aol.com

Contract Number:	Contract Amount:	Funding Year
40323	$381,000	FY95

Start Date:	Completion Date:
January 1996	May 1997

12.1 BACKGROUND AND TECHNICAL DESCRIPTION

12.1.1 Background

The Doppler principle is a powerful technique that is used extensively in microwave radar to extract targets buried in clutter, but it has never been applied to ocean optics. One of the main obstacles has been the speckle noise inherent in Doppler-coherent laser backscatter from ocean water. Mission Research

Corporation discovered an elegant solution based on optical parallel processing so that Doppler can be used in ocean optics.

Ocean Doppler Lidar (ODL) is a breakthrough for long range shipboard detection of underwater moving objects like torpedoes launched from a submarine, or the submarine itself. Figure 12.1 shows an example deployment of the ODL. Other applications of ODL include locating whales or schools of fish.

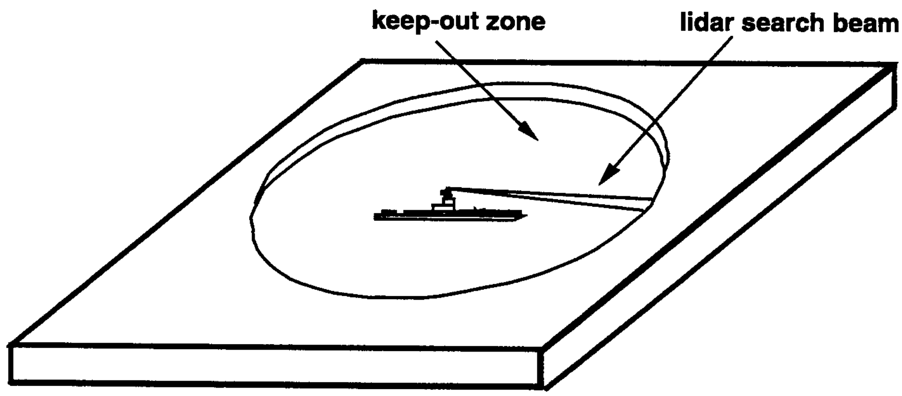


Figure 12.1 Example deployment of Ocean Doppler Lidar

12.1.2 Technical Description

A blue-green laser (Nd:YAG, operating at 532nm) beam is expanded by a telescope to a 10 cm diameter and then illuminates the target. Light returned from the target is collected by a 10 cm telescope and directed to the moving-target-indicator filter. The light passed by the filter is collected and detected with a Hamamatsu 928 photodiode. The data acquisition computer (133 MHz Pentium PC) also controls the reference and filter cavities. Figure 12.2 shows the schematic diagram of the ODL system.

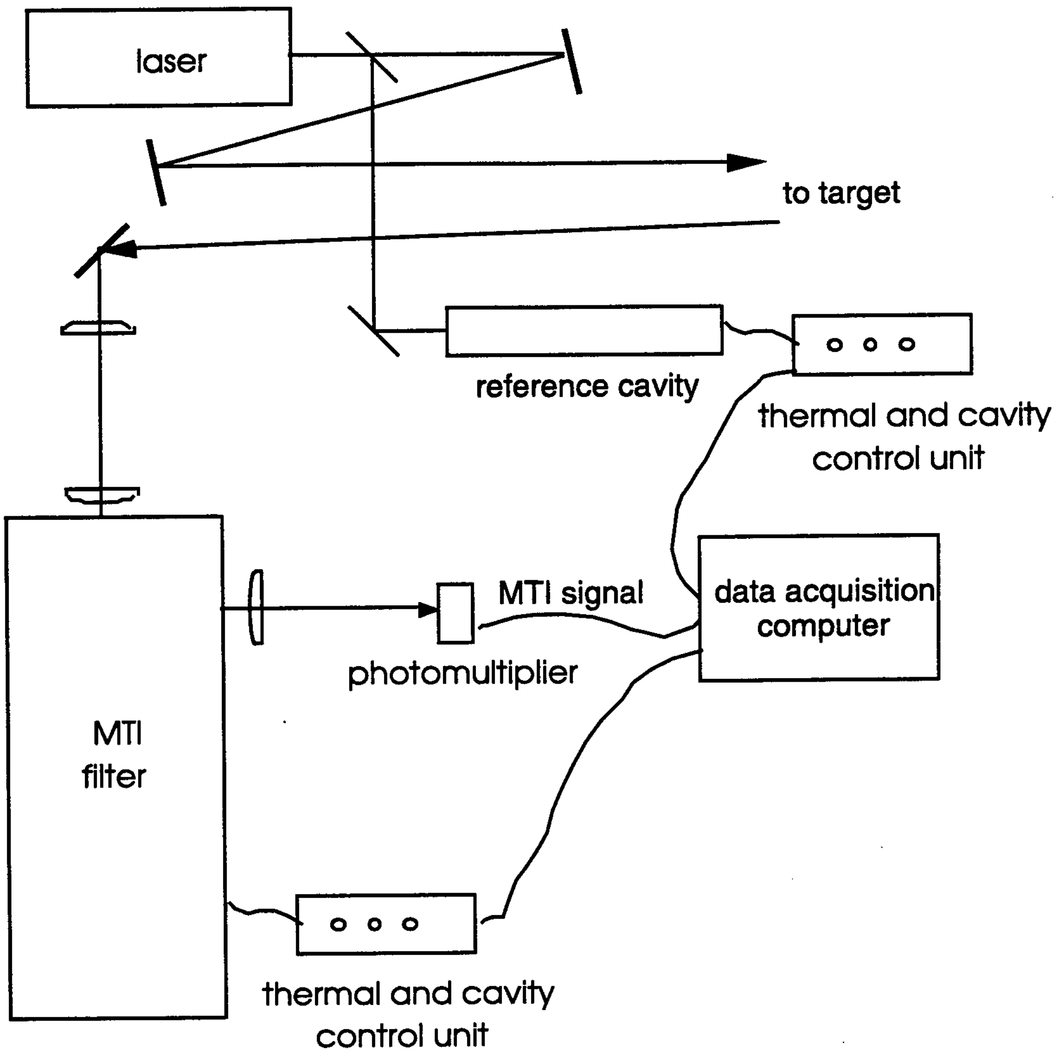


Figure 12.2 ODL schematic diagram

The MTI filter is the unique technology in the ODL system. The filter consists of an optical resonant cavity with apertures and lenses to control the flow of energy. The unique optical cavity invented by MRC enables optical signals to be Doppler-processed in parallel. Conventional heterodyne detection would require the electronic processing of 10^5 speckle channels, whereas the MRC approach processes them optically. This innovation makes practical the implementation of coherent Doppler lidar for this application. In addition, it enables the coherent combination of light to overcome the speckle noise from these 10^5 channels. This makes possible a 40 dB reduction in quantum noise, permitting the use of an eye-safe laser.

12.2 OBJECTIVES

This project sought to demonstrate the feasibility of detecting underwater moving targets with a laser radar. The technical objectives of this project were:

(1) to establish the optical Doppler signature as a reliable target-from-clutter discriminant in ocean optics; and (2) to establish the existence of a practical means to exploit the principle. Success in the proof-of-principle demonstration would reduce technical risk for further development of the concept under ARPA or ONR sponsorship.

12.3 PROJECT ENVIRONMENT

The optical filter was built and tested in the laboratory of Mission Research Corporation in Los Angeles, California. Ocean field tests were conducted from University of Hawaii buildings and in the ocean test range of the University of Hawaii's Ocean Engineering Department located at Kakaako Peninsula, Oahu which are shown in figures 12.3a and 12.3b respectively.

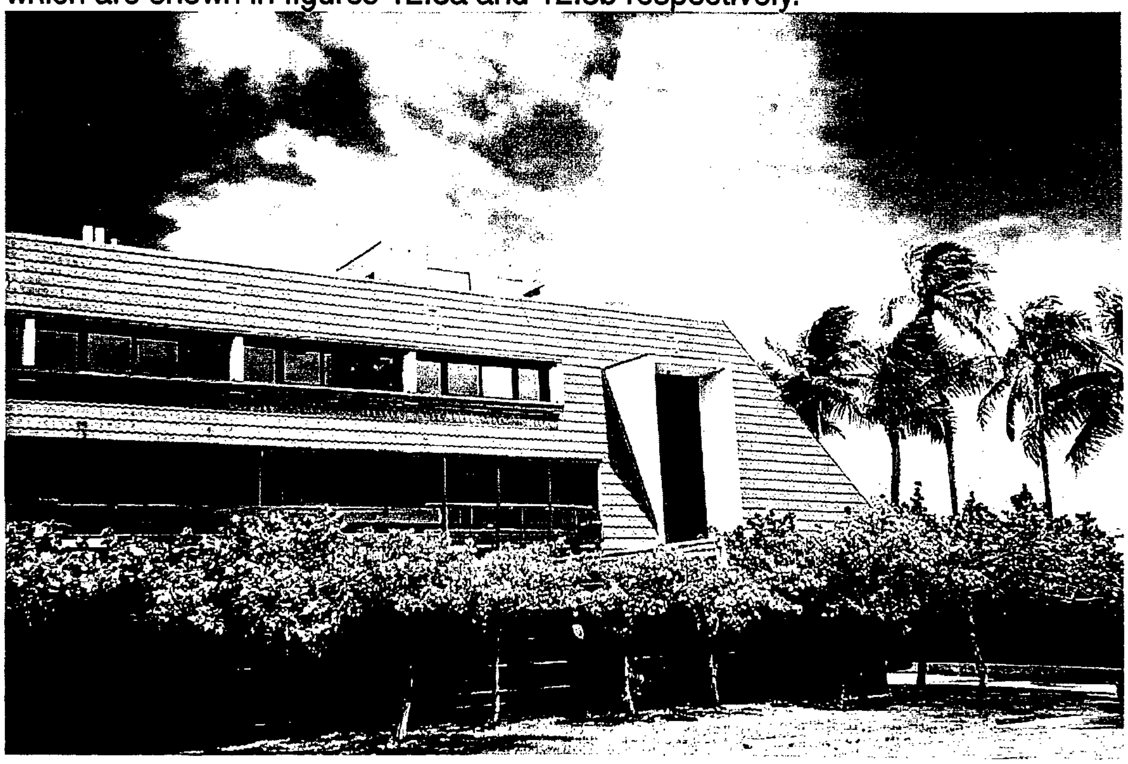
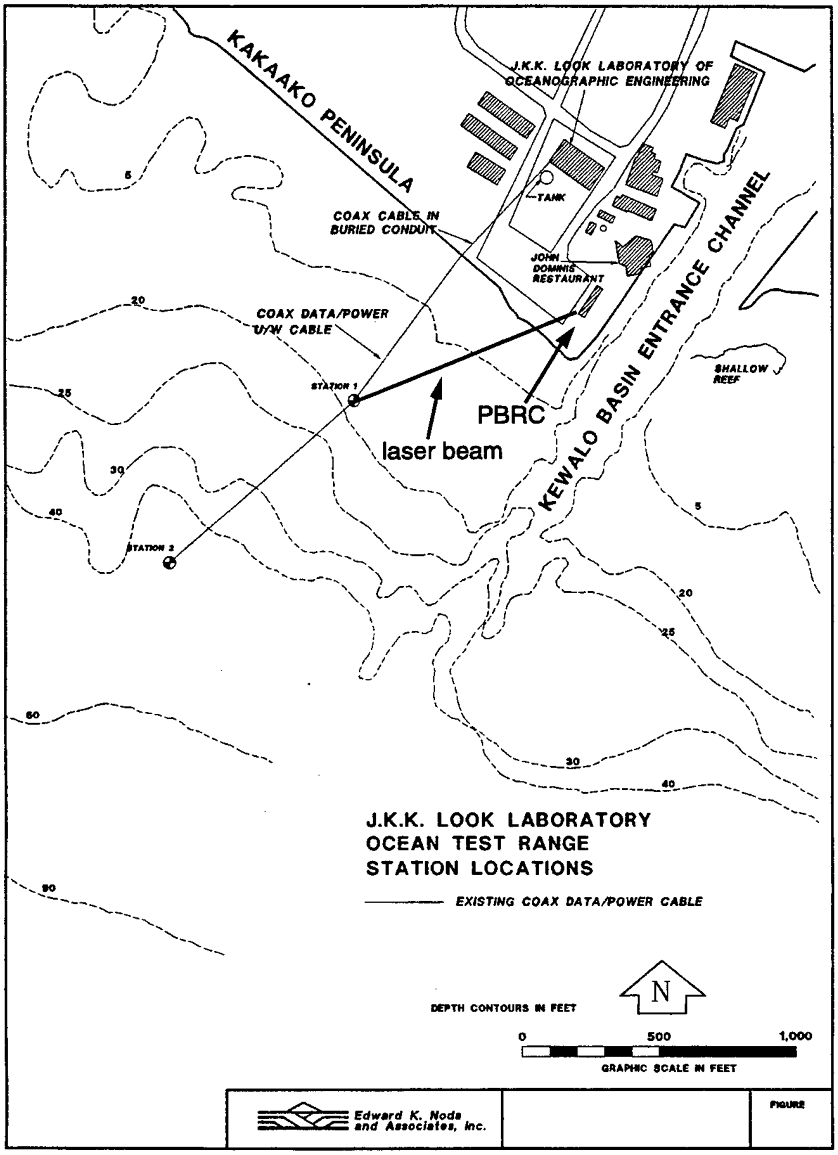


Figure 12.3a University of Hawaii's Ocean Engineering Department



12.3b University of Hawaii's Look Laboratory Ocean Test Range

12.4 METHODOLOGY AND RESULTS

This work involved the assembly and laboratory testing of an optical Doppler filter, the demonstration of the filter in a lidar system, and the detection of the Doppler signal of a moving target in the ocean. The project demonstrated that this Doppler filter is capable of rejecting clutter and passing the target signal in "realistic ocean conditions", thus confirming the Ocean Doppler Lidar concept.

The ODL concept is based on two assumptions: (1) that significant optical energy can be coupled into the water at the extremely shallow grazing angles of shipboard operation, and (2) that under illumination by coherent light the Doppler

signature of an underwater moving object is clearly distinguishable from that due to water backscatter.

The optical filter invented by MRC features a unique optical cavity configured as a moving target indicator (MTI) notch filter. To function successfully, the MTI filter must optically provide a narrow linewidth, a deep null, and a wide field of view. With these features it becomes feasible to eliminate water backscatter as a source of clutter in detecting underwater moving objects.

A great advantage of ODL is that it detects objects at long range from a shallow grazing angle. This makes it useful for ship self-defense against underwater threats in shallow waters. The performance model predicted that a submarine at a range of 10 km would be detected at a depth of 30 m, well before it has an opportunity to deploy its periscope. This capability is significant for two reasons: (1) 10 km is beyond the range of conventional torpedoes, and (2) it opens the potential of suppressing use of the periscope altogether, thereby severely degrading the submarine's targeting capability. The model also predicted that an incoming torpedo at a depth of 50 m would be acquired at a range of 4000 m, and tracked with an accuracy better than 5 m CEP.

MRC engineers built and tested the ODL in their labs in Los Angeles, California. Laboratory tests were successful so the project progressed to field tests in the ocean.

Field tests were conducted at the J.K.K. Look Laboratory Optical Test Range operated by the University of Hawaii. The physical lay-out of the tests simulated deployment on a ship. The ODL was mounted on the roof of the three-story PBRC building. This is comparable to the height of deployment on a ship. To be effective, the object must be moving by 2 knots or greater so the ODL can use the object's Doppler signature. A moving belt target was moored in the ocean at 5 m depth near station 1 of the Test Range, a distance of 200-300m from the ODL on the roof. The range to the target was subscale, but the grazing angle was equivalent to a full-scale system operating from a ship.

Researchers observed unmistakable lidar signatures when the ODL scanned the target. This initial detection of an underwater moving object with a laser achieved over 15 dB target-to-clutter ratio at shallow grazing angles. This is a huge improvement over previous tests at NRaD in 1978 that achieved a 0.8 dB ratio. In summary, MRC constructed an all-optical Doppler filter with predicted properties and demonstrated the utility of the filter to detect the Doppler signature of a submerged moving object and to reject potentially confounding motion associated with ocean motion ("clutter").

12.5 PRODUCTS

12.5.1 Commercial Products

This technology demonstration was too early in the design cycle to result in a commercial product.

12.5.2 Papers, Patents, and Disclosures

No papers, patents, or invention disclosures resulted from this contract.

12.6 IMPACT

12.6.1 Job Creation

At MRC, this contract supported a senior scientist/engineer at 0.75 FTE, a technician at 0.27 FTE, and about forty hours of technical support. The subcontract to Edward K. Noda & Associates totaled $91,000 and mainly supported labor costs.

12.6.2 Business Development

Based on this work, MRC conceived a "Torpedo Defense Doppler LIDAR" and presented it at a classified ONR torpedo defense workshop on May 18, 1999.

12.6.3 Residual Benefits to Hawaii

Hawaii engineers at the UH Look Laboratory and at Edward K. Noda & Associates benefited from working with this cutting edge technology. One quarter of this contract was a direct pass-through to the subcontractor Edward K. Noda & Associates.

12.6.4 Principal Investigator/Company Opinion

The contractor found the CEROS project to be a very positive experience, with a good balance of oversight and freedom of action for its scientists.

12.6.5 Impact on Principal Investigator/Company

The contractor did not respond to this question.

12.7 TRANSITION

The project's Principal Investigator briefed ONR program officers in the Engineering, Materials, and Physical Science and Technology Department, Mine Countermeasures Program, and Sensing Information Department about the test results and potential for development of a shipboard system.

The following is proprietary information: MRC proposed a three-year project to conduct a terminal torpedo defense demonstration using the ocean doppler lidar. The counter-weapon will likely be a Gatling Gun, under development at NUWC-Newport, that fires special 20mm super-cavitating rounds through water. A proposal for FY00 is currently under evaluation at ONR.

13.0 Diver Homing Device

ABSTRACT

Neptune Technologies, Inc. designed, built, and field tested a prototype electro-acoustic system that allows a diver to home on an ultra-sonic transmitter. To improve directional sensitivity, the device is designed to use the diver's body and equipment as an acoustic shield.

The receiver and transmitter are compatible with other diver-carried accessories. An indicator light on the receiver illuminates only when the diver is aligned with the transmitter. The transmitter is small enough to be moved by a diver. The Diver Homing Device has an effective range of at least 20 times dive depth for depths not exceeding 25 meters; the maximum design range is 500 meters. Both transmit and receive units are powered by self-contained batteries with a minimum lifetime of 10 hours per unit.

A particular feature of the Diver Homing Device is the design that uses the diver's body and equipment as an acoustic shield to increase directionality. Neptune Technologies noted, however, that multipath reflections and reverberation from the sea surface or bottom may reduce directionality for some sea or bottom conditions. Several simple techniques were tried to adjust transmitter output to minimize reverberation and maximize directionality for various environmental conditions. Overall, the device proved efficient for a wide range of environments and conditions.

The Diver Homing Device met or exceeded all performance requirements and contract specifications. Neptune Technologies is preparing to test the device further in "real world" situations, with an eye toward commercialization and production of a final product. Neptune Technologies received a United States patent for technologies related to this CEROS-sponsored demonstration project.

Contractor: Neptune Technologies, Inc.
Post Office Box 412
Kailua, HI 96734
phone: 808-259-7177

Principal Investigator: Mr. Jack Harmon, Mr. Jack Holzschuh
jackhi@hawaii.rr.com

Contract Number:	Contract Amount:	Funding Year
40295	$200,000	FY95

Start Date:	Completion Date:
February 1996	March 1997

13.1 BACKGROUND AND TECHNICAL DESCRIPTION

13.1.1 Background

Putting persons in the ocean to observe, interact, or perform a task has been the backbone of ocean science and technology advances. Scuba diving is widespread in the DoD and private sectors. Over the past two or three decades, the bulk of DoD's investment in diving technology has been directed toward

improved life support systems. Because the equipment is better, divers can work more under adverse conditions like poor visibility, currents, surges, and water temperature extremes.

A major safety hazard for the divers under these conditions is loss of orientation. A common cause of loss of orientation is losing visual contact with the work site. Then the diver must surface, find a surface marker, and follow a buoy line back to the work site. During this period no work is done, the diver's partner may also have to surface, the task is disrupted, and both divers are placed at risk.

The primary reason to develop the Diver Homing Device (DHD) is diver safety. The DHD will allow a diver to place a transmitting beacon at the worksite and carry a small receiver that is used when needed to find the beacon. The large sport diver market will buy the device to mark the point of entry on the beach or boat to return to, or to place the beacon near a lobster hole or other site of interest found during the dive.

13.1.2 Technical Description

The Diver Homing Device (DHD) consists of three basic components, the transmitter, the receiver, and the scuba diver. The transmitter is used to mark the site the diver desires to be directed to. The receiver is used to indicate the direction to this site. The scuba diver is an acoustic shield used to eliminate directional ambiguity.

The transmitter housing (shown in Figure 13.1) measures 4 ½ in. in diameter by 7 in. long. The transmitter weighs 4 lbs. with battery and is negatively buoyant. The battery is a Duracell PC 915 or equivalent 6V alkaline lantern battery. The lifetime is in excess of 100 hours continuous. The transmitter generates the sound that is detected by the receiver and used to guide the diver to the transmitter. It is basically a conventional "pinger" comprised of a gated oscillator, a driver amplifier, a transformer, and a ceramic transducer. It operates at 100 kHz frequency. The transmitter source level is 126 dB re 1 μ Pa/V. Figure 13.2 shows the Transmitter Schematic.

Figure 13.1 Diver Homing Device Transmitter

Paste Transmitter schematic here

The receiver housing (shown in Figure 13.3) measures 3 ½ in. wide, 1 ½ in. thick, and 6 7/8 in. long. The receiver weighs 1 ¼ lbs with battery and is negatively buoyant. The battery is a Duracell MN 1604 or equivalent 9V alkaline transistor battery. The lifetime is in excess of 70 hours continuous operation. The receiver detects the sound generated by the transmitter and indicates to the diver the direction to the transmitter. A red light emitting diode (LED) lights when the receiver detects the transmitter. It is comprised of a ceramic hydrophone, an amplifier, a detector, and a LED. It contains battery check circuitry for convenience. The receiver responds (lights the LED) when the output voltage of the ceramic hydrophone is 70 μV peak to peak. The receiver hydrophone sensitivity is -200 dB re 1 V/μ Pa. Figure 13.4 shows the Receiver Schematic.

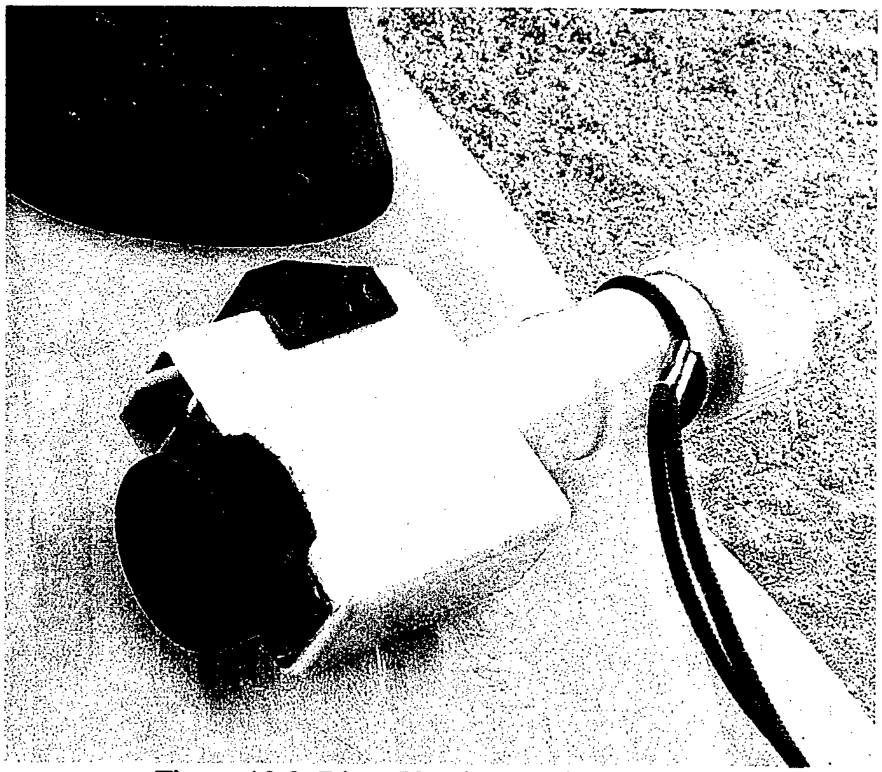


Figure 13.3 Diver Homing Device Receiver

13.2 OBJECTIVES

Neptune Technologies sought to design, fabricate, and test an electro-acoustic Diver Homing Device (DHD). The DHD consists of two acoustic sub-systems, a diver-worn receiver, and an ultra-sonic transmitter that can be placed at the site the diver desires to home on. When operating, it will guide a diver to the desired site simply by directing the diver to swim in an indicated direction.

13.3 PROJECT ENVIRONMENT

Neptune Technologies conducted this work in electronics labs on Oahu. Field tests were conducted in the Pacific Ocean around Oahu.

Paste receiver schematic here

13.4 METHODOLOGY AND RESULTS

Neptune Technologies followed a system approach to design the DHD with the following features: (1) receiver compatible with other diver-carried accessories; (2) indicator light illuminates only when diver faces the transmitter directly; (3) transmitter small enough to be placed or moved by a diver; (4) range of at least 20 time dive depth for depths not exceeding 25 m. and maximum range of 500 m; (5) receiver and transmitter use self-contained batteries for power with battery lifetime of 10 hrs or more. System design criteria included the electronic design, power consumption, packaging, human factors, and acoustics.

The receiver uses a transducer, and receiver electronics that are on a printed circuit board (PCB). The PCB uses surface mount devices that are 1/3 to 1/10 the size of normal (lead-mounted) components. The receiver demonstrated low power consumption; it operated continuously for over 70 hours on a single 9 volt alkaline "transistor" battery. For a weekend sport diver doing 4 dives each weekend, and using the receiver 30 minutes on each dive, this equates to a battery change every 8 months. The receiver packaging features a rectangular top portion that houses the electronics and transducer, and a cylindrical handle that houses the battery. The LED is on the top of the rectangular portion and lights only when the receiver is turned on and is receiving the transmitter signal. It is small and light so it can be hooked to the diver's vest and deployed only when needed. This configuration is comfortable to use and encourages the diver to hold the receiver in its most effective orientation.

The transmitter incorporates a gated oscillator, a driver amplifier, a transformer, and a ceramic transducer to generate acoustic pings to be detected. The transmitter is powered by a Duracell PC 915 or equivalent 6V alkaline lantern battery that fits in the housing with the electronics. During testing, the transmitter operated in excess of 100 hours of continuous use, and the calculated battery lifetime is 400 hours. For the sport diver cited above, the transmitter battery would need changing every 1.3 years. The transmitter weighs less than 5 lbs in air and is negatively buoyant in water. So it can be placed by the diver, or even could be worn by the diver for location by another diver.

The compact size of the receiver and transmitter means that they do not interfere with other diver-carried accessories. The range goal was also met because the maximum range demonstrated was over 800 m. All design goals were met and the DHD functioned successfully.

13.5 PRODUCTS

13.5.1 Commercial Products

The Diver Homing Device system is being prepped for the military and commercial markets as of the time of this writing. The transmitters and the

receivers will be manufactured in Hawaii and marketed worldwide. The DHD is expected to have widespread application, particularly as a way to increase the efficiency of divers working in adverse conditions such as poor visibility, currents, surges or extreme water temperatures.

13.5.2 Papers, Patents, and Disclosures

Neptune received patent number 5,666,326 on September 9, 1997 for "Homing Device for Underwater Divers."

The following paper was presented: A Simple Homing Device for Divers. Jack E. Holzschuh. Pacific Congress on Marine Science and Technology, 1996 (PACON '96), Honolulu, Hawaii, June 17-22, 1996, p. 14.

13.6 IMPACT

13.6.1 Job Creation

This contract supported 2.5 positions comprised of a senior engineer, electronic technician, and a half-time administrative position. There were subcontracts to Bear Machinery of Oahu.

13.6.2 Business Development

Neptune is gearing up to manufacture the DHD in Hawaii with Bear Machinery of Oahu willing to contribute some start-up costs. They are looking for capital to go into large-scale production. In the interim, they are filling custom orders as they are received.

13.6.3 Residual Benefits to Hawaii

The DHD will be manufactured in Hawaii and sold and distributed from Hawaii. Neptune also has a contact looking for a production and distribution site in Europe.

13.6.4 Principal Investigator/Company Opinion

The Principal investigator stated that the CEROS program provides excellent seed money for new ideas and capabilities. CEROS is good for Hawaii industry.

13.6.5 Impact on Principal Investigator/Company

The CEROS funding was a godsend that allowed Neptune to build and test the DHD.

13.7 TRANSITION

Neptune received $40,000 in FY97 and $25,000 in 1999 from CEROS to improve the DHD and to provide three sets of receivers and transmitter beacons to the Navy Special Warfare Center in San Diego. This Navy filed unit will use the DHD for operational testing and use.

The commercial market plans are discussed in section 13.6.

14.0 SWATH Motion/Structural Software Development

ABSTRACT

Ocean Engineering Consultants, Inc. created and/or adapted engineering design software code to design and test Small Waterplane Area Twin Hull (Swath) ships. With funding in CEROS FY94, FY95, and FY96, OEC sought to develop and validate a software tool to calculate and visualize flow patterns around and in the vicinity of a Swath-type hull. OEC conducted an integrated software development to create a "numerical tow tank" for Swath and multi-hull vessels, to extend software capabilities, test and verify the software, and to provide a preliminary guide for finite element model. The software package has three analytic options: quasi-static, hydro-elastic, and rigid-dynamic. It is particularly useful for critical placement and flow alignment of hull appendages, and for analyzing Swath vessels in special situations, such as close running with another vessel or oceanographic instrument deployment. This sophisticated software decreases the time and cost necessary to design faster, more stable ships for the military and civilian markets. Ocean Engineering Consultants, Inc. markets its engineering design services worldwide and features Swath ship designs with its advanced software tools.

Contractor: Ocean Engineering Inc.
2250-A Noah Street
Honolulu, HI 96816
phone 808-735-2775

Subcontractor: None

Principal Investigator: Dr. Ludwig Seidl
OEC@Hawaii.RR.com

Contract Number:	Contract Amount:	Funding Year
38081	$121,000	FY94
40464	$168,000	FY95
41366	$161,372	FY96

Start Dates:	Completion Dates:
October 1994	September 1995
March 1996	June 1997
October 1996	September 1997

14.1 BACKGROUND AND TECHNICAL DESCRIPTION

14.1.1 Background

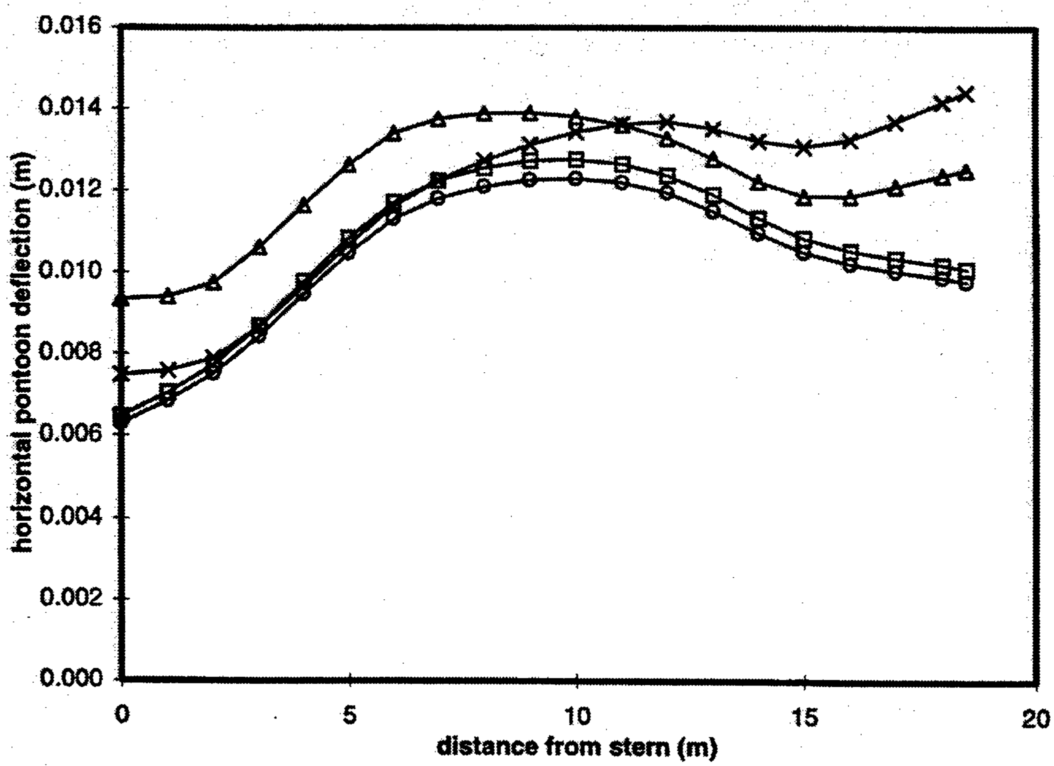
The DoD needs fast, stable ships able to operate in rough seas and in shallow waters. Swath ships offer many advantages over conventional v-hull ships to address these requirements. Swath ships also meet the needs of the commercial market for small and medium passenger vessels. A comprehensive

tool for rationally-based structural and hydrodynamic analysis, including flow calculation and visualization, is needed to reduce the technical risk for new designs. The customer for a Swath design may not be acquainted with the configuration and performance of this vessel type. Conveying to a potential buyer how a particular Swath design will look and perform is a crucial marketing task. The ability to "show the flow" will permit the design professional to show the customer far more than a table of engineering specifications.

Ocean Engineering Consultants (OEC) provided its proprietary software VESDYN (name coined from "vessel dynamics") as the basis for the Swath software. VESDYN can analyze vessel dynamics, ship motions, structural stresses, and other computations to assist with vessel design.

14.1.2 Technical Description

OEC's Swath ship software computes the entire range of analysis capabilities from standard hydrostatic and hydrodynamic calculations, ship motions analyses, resistance calculations, flow visualization, and rational structural analysis by the quasi-static and dynamic methods. The software has three analytic options: quasi-static, hydro-elastic, and rigid-dynamic. For example, Figure 14.1 shows the pontoon deflections for beam waves from the three analytic methods.



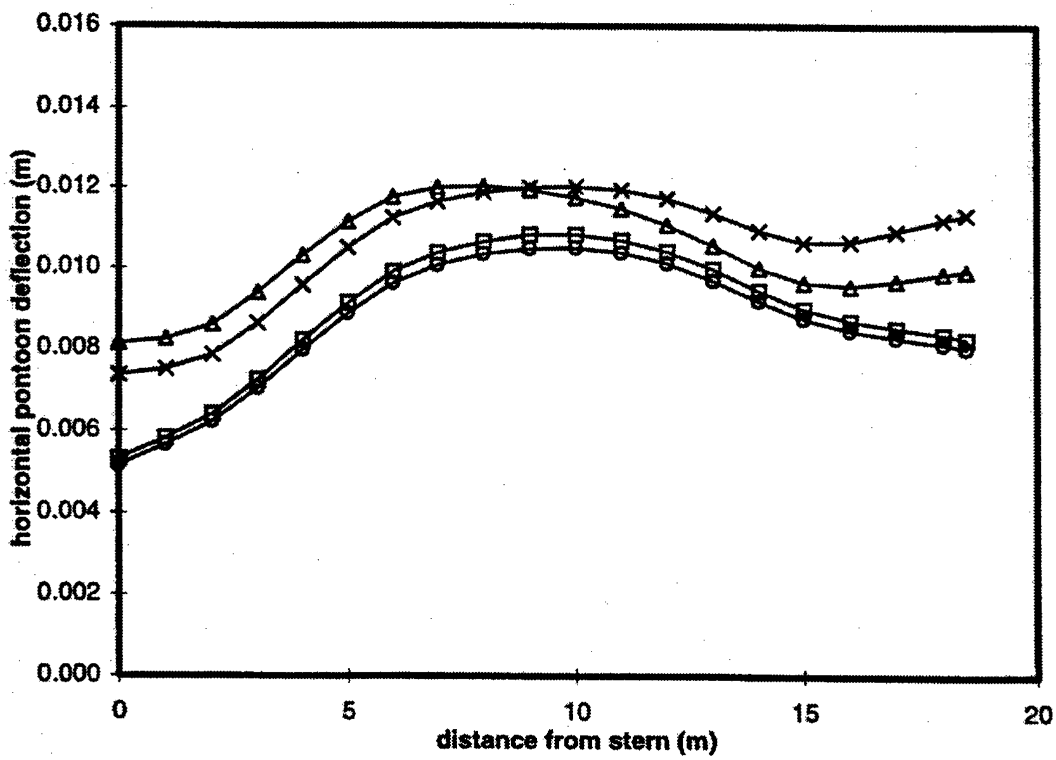


Figure 14.1 Horizontal pontoon deflections for regular beam waves of unit amplitude (a) 3.5 sec. (b) 4.0 sec. Δ, hydro-elastic (port); x, hydro-elastic (starboard); , rigid-dynamic; O; quasi-static.

14.2 OBJECTIVES

Create a software package to design and test fast, stable, Small Waterplane Area Twin Hull (Swath) ships. The software package would provide naval architects with numerical tow-tank testing to reduce design time and costs.

14.3 PROJECT ENVIRONMENT

Ocean Engineering Consultants engineers performed computer programming and software testing at its offices in Honolulu. OEC engineers visited software vendors in the Netherlands and Germany to evaluate and train on computational fluid dynamics (CFD) software to be ported to OEC's VESDYN for the final Swath software package.

14.4 METHODOLODY AND RESULTS

During FY94 OEC began developing a practical software package for coupled hydrodynamic/structural analysis of Swath ships. The analysis included the rigid body, the elasticity, and the vibratory response of the Swath structure to improve the accuracy of predictions of fatigue behavior as compared to conventional quasi-static analysis methods. As an intermediate result of this effort, the quasi-static analysis was extended to allow for an automatically computed loading based on 3-D hydrodynamic analysis and its automatic transfer to the structural FEM (finite element model) analysis. Conventional quasi-static methods relied on empirical formulation of the hydrodynamic loading or on 2-D methods. The twin-hulled structure in beam seas can be compared to a tuning fork, whereby the vibratory behavior is determined by the elasticity of the structure and the mass effects of the surrounding water. Figure 14.2 shows a typical section of a Swath ship created with the OEC software. The technical term for the required analysis is hydro-elasticity, i.e. analysis of the elastic structure in the presence of the surrounding water. Excessive vibrations can be objectionable to passengers and most importantly can lead to fatigue failure of the structure.

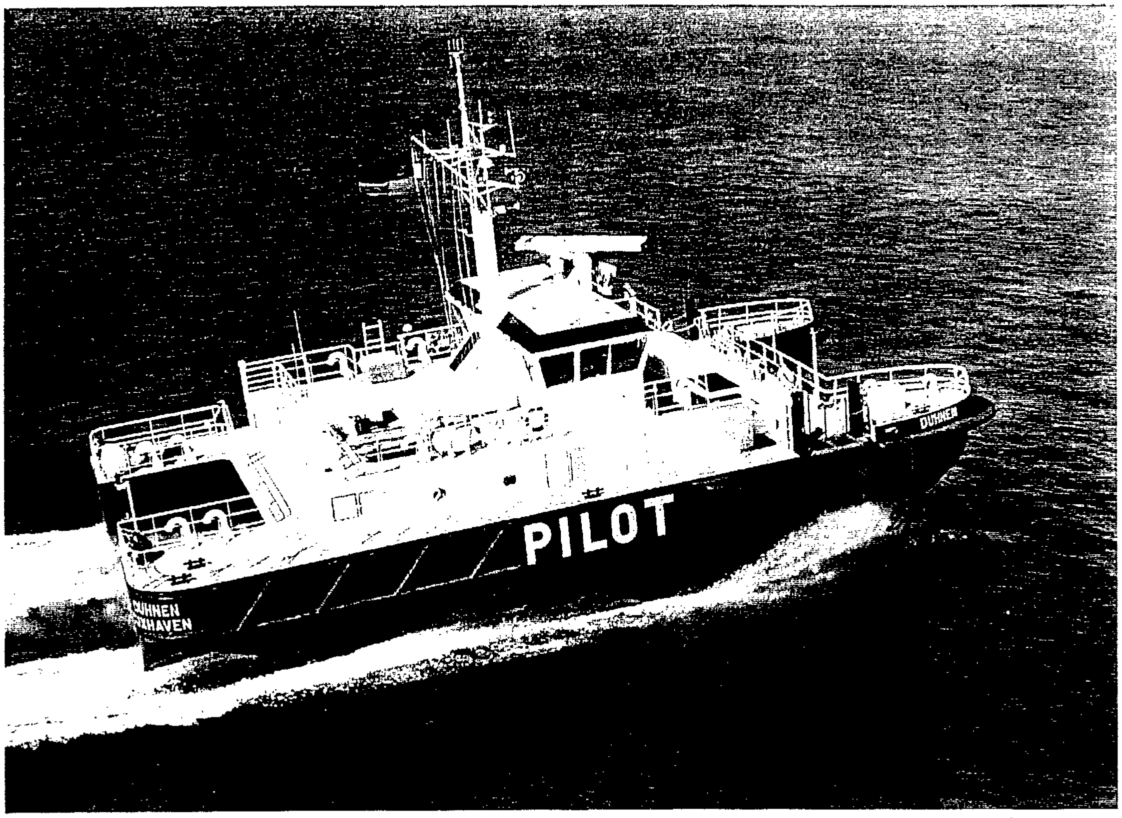


Figure 14.2 Swath ship created with the OEC software

During FY95, OEC sought to extend software capabilities, test and verify the software, and provide a preliminary guide for FEM analysis. Significant improvements in the software were reported, including incorporating oblique wave headings, irregular seas, automated load combinations, local fine-mesh analysis and concentrated loads and local modes. Additionally, the program was extended to include the rigid-dynamic approach, which is commonly used by certifying agencies. Thus the final software package has three analytic options: quasi-static, hydro-elastic, and rigid-dynamic.

The computer package evaluates hydrodynamic pressure by the source distribution method and models structural deformation and stress by the finite element method. Figure 14.3 shows the hydrodynamic grid for a Swath ship, and Figure 14.4 shows the finite element grid for a Swath ship. Pressure distributions and responses are separated into symmetric and anti-symmetric components that can be evaluated separately using only half the vessel. This approach reduces computing time and produces more manageable data files. The software was verified by comparing calculated prying forces with measurements and comparing structural deformations and stresses obtained for the three approaches. The quasi-static and rigid-dynamic approaches give very similar results; for the lower hull, the hydro-elastic approach is expected to give more accurate predictions of deflection and stress.

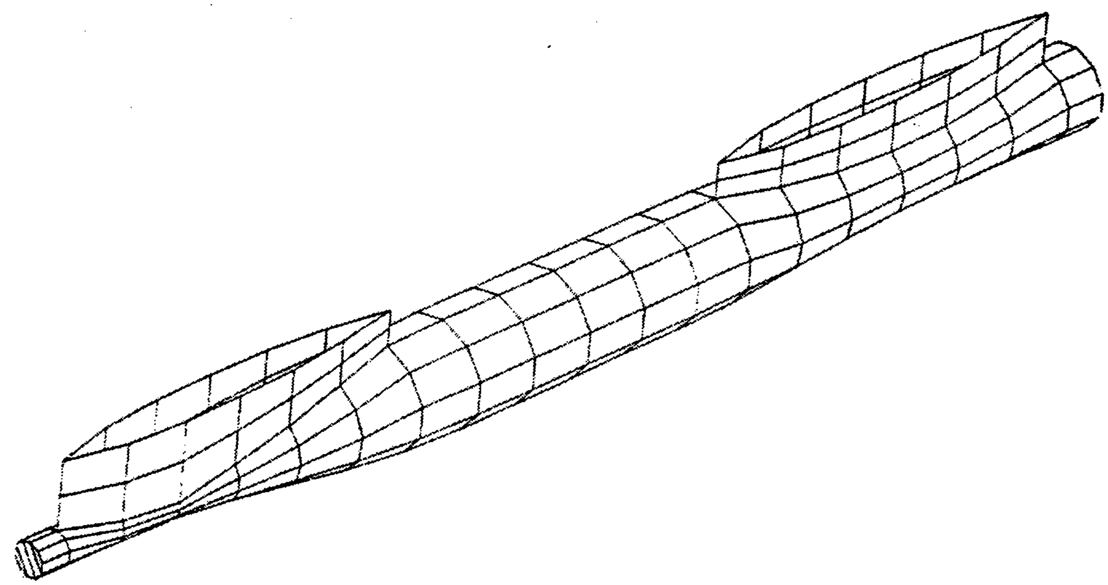


Figure 14.3 Hydrodynamic Grid for the Swath Ship S20T10

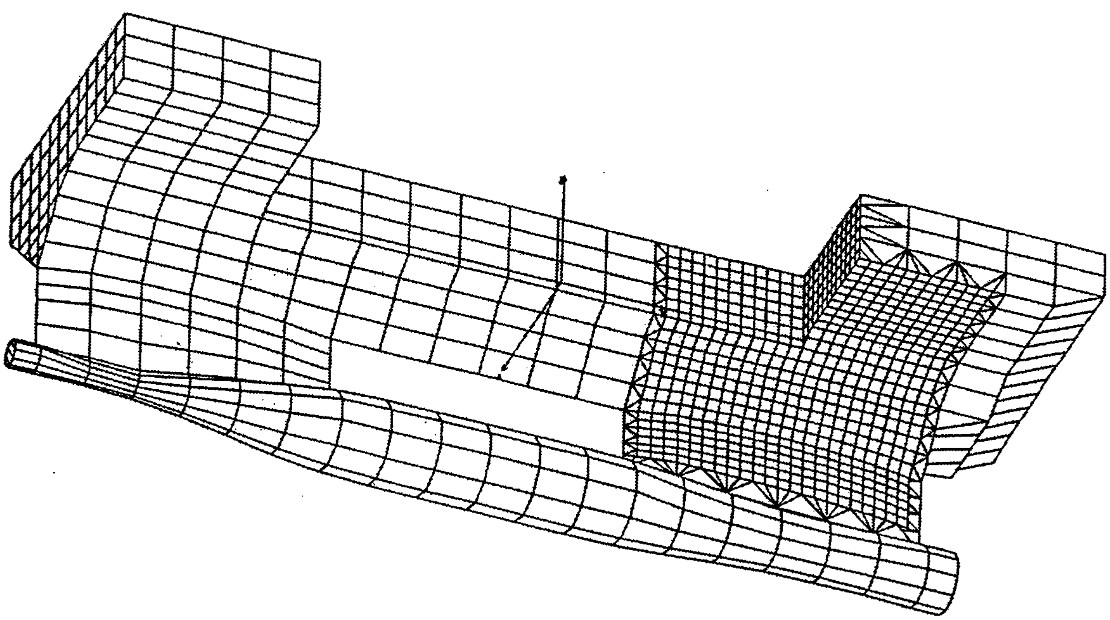


Figure 14.4 Finite Element Grid for the Swath ship S20T10

During FY96, OEC extended their Vesdyn software capability through acquisition of commercially developed CFD (computational fluid dynamics) code, then customized that software and extended the application for Swath ships. The

revised software was demonstrated in an application to a twin-strut Swath ship. OEC now has a sophisticated software package for calculations required for designing Swath ships. Analytic capability was significantly enhanced by incorporation of static and dynamic structural computational techniques.

Flow visualization and simulation capabilities, which are required for rapid design of Swath hulls, were also developed during FY96. The final package is particularly useful for critical placement and flow alignment of hull appendages and for analyzing Swath vessels in special situations, such as close running with another vessel or oceanographic instrument deployment.

14.5 PRODUCTS

14.5.1 Commercial Products

Due to the development of this unique, proprietary software, OEC attracts service contracts worldwide to design Swath ships. No retail products were developed.

14.5.2 Papers, Patents, and Disclosures

The software created under these contracts is proprietary to Ocean Engineering Consultants, Inc.. No patents or invention disclosures were filed.

OEC published two papers about this work:

Comparison of Structural Analysis Methods for Swath Ship Design. L.H. Seidl, K.F. Cheung, and S. Wang. Proceedings of the Seventh (1997) International Offshore and Polar Engineering Conference (ISOPE 97), Honolulu, Hawaii, USA, May 25-30, 1997, Vol. IV, pp. 689-696.

Analysis of Swath Ship Structures. K.F. Cheung, L.H. Seidl, and S. Wang. Marine Technology, Volume 35, No. 2, The Society of Naval Architects and Marine Engineers, April 1998.

14.6 IMPACT

14.6.1 Job Creation

This project supported three half-time engineering and computer programming positions.

14.6.2 Business Development

The design of new ships predominantly is marketed to shipyards on an individual basis, through personal connections.

14.6.3 Residual Benefits to Hawaii

The proprietary software enables OEC to maintain its position as a worldwide leader in advanced ship design. OEC brings about $200,00 in service contracts to this Hawaii business each year.

14.6.4 Principal Investigator/Company Opinion

The contractor thinks that CEROS plays a fundamental and necessary role to help Hawaii technical companies to compete in the national and international arena.

14.6.5 Impact on Principal Investigator/Company

The support from CEROS helped OEC immensely to obtain a leading capability in its chosen field of design of Swath vessels. This leadership in design and analysis of Swath made it possible to obtain another exclusive four-year contract with a European shipyard. With this shipyard the OEC has delivered two Swath-type pilot ships to the owner, and a third ship, a 50 m, 1400 ton Swath has been launched and is nearing completion.

14.7 TRANSITION

CEROS awarded follow-on funding for a total of three years to this project (FY94, 95, and 96). Ocean Engineering Consultants, Inc. received a long-term (four-year) design contract from a major European shipyard because of the software improvements supported by CEROS. The immediate goal is to establish similar exclusive license agreements with shipyards worldwide. Typically the exclusivity is given for one country.

The contractor points out that the art of design and analysis of Swath ships is developing continuously, and it is necessary to keep their lead by diligently enhancing their capabilities. The last major effort in our CEROS funded software development is now four years in the past and the development of the computer industry over the last four years is evident to everyone. OEC will seek funding to create new Swath software.

15.0 Underwater Echolocation for Buried Objects

ABSTRACT

This three-year effort by ORINCON Corporation and the Hawaii Institute of Marine Biology (HIMB) of the University of Hawaii focused on attaining "dolphin-like" echolocation performance to detect and classify buried objects in cluttered environments using a prototype, real-time, automated broadband active sonar system. The ORINCON team defined dolphin echolocation performance criteria, developed the biomimetic signal and information processing system to match that performance, and demonstrated the system integrated on a bottom-crawling remotely operated vehicle (ROV). The real-time signal processing was performed with proprietary ORINCON software and commercial off-the-shelf (COTS) hardware provided to HIMB by the Office of Naval Research.

During this effort, ORINCON also implemented a signal processing model based on the dolphin cochlear system and quantified the model's performance. Overall, ORINCON demonstrated (1) that their biomimetic signal and information processing system could -- in real-time -- effectively represent, detect, and classify underwater echolocation returns from objects located on the bottom or buried in the sediment; (2) that a multifeature fusion classification system can achieve a level of performance greater than that of an individual feature-based system; and (3) that models, such as those based on wavelet transform and the dolphin cochlea, show particularly promising signal representation capabilities.

Contractor: ORINCON Hawaii, Inc.
970 N. Kalaheo Ave
Suite C-215
Kailua, HI 96734
phone: 808-254-1532

Subcontractor:
Hawaii Institute of Marine Biology
P.O. Box 1106
Kailua, HI 96734
phone: 808-236-4001

Principal Investigator: Mr. Gerald Moons
jerry@orinconhi.com

Contract Number:	Contract Amount:	Funding Year
38082	$652,685	FY94
39503	$696,926	FY95

Start Date:	Completion Date:
October 1994	October 1995
September 1995	October 1996

15.1 BACKGROUND AND TECHNICAL DESCRIPTION

15.1.1 Background

Navy sonar operators use the echo returns from active sonar to locate and classify underwater objects. These objects may be on the seabed, buried under sediment, or tethered from the ocean floor. Manual interpretation of these sonar echo returns can be very time consuming, and the results depend on the operator's skill. The Navy needs improved sonar processing to meet fleet needs.

In certain situations, the Navy uses the biological sonar ability of dolphins and small whales. The MK 7 Marine Mammal System is the Navy's most effective mine-clearance system, and the only method available to detect and classify buried objects. No man-made sonar has been developed that can approach the performance of this system in highly reverberate and noisy shallow-water environments.

ORINCON has taken advantage of unique access to trained bottlenose dolphins and biosonar expertise at the Hawaii Institute of Marine Biology (HIMB) to forge a unique capability for research not available elsewhere. HIMB provides data from dolphins and insight into signal processing mechanisms that ORINCON integrates into the signal processing scheme.

15.1.2 Technical Description

The ORINCON team defined dolphin echolocation performance criteria, developed the biomimetic signal and information processing system to match that performance, and demonstrated the system integrated on a bottom-crawling remotely operated vehicle (ROV). The real-time signal processing was performed with proprietary ORINCON software (Real Time Interactive Programming and Processing Environment, RIPPEN®) and commercial off-the-shelf (COTS) hardware. The primary RIPPEN® processing tools have been arranged in a functional block diagram as shown in Figure 15.1. In order to use active sonar returns to detect, classify, and localize targets located in the water column, on the seabed, or buried under bottom sediment, a biomimetic multifeature fusion signal and information processing system was developed and implemented within ORINCON's RIPPEN® software.

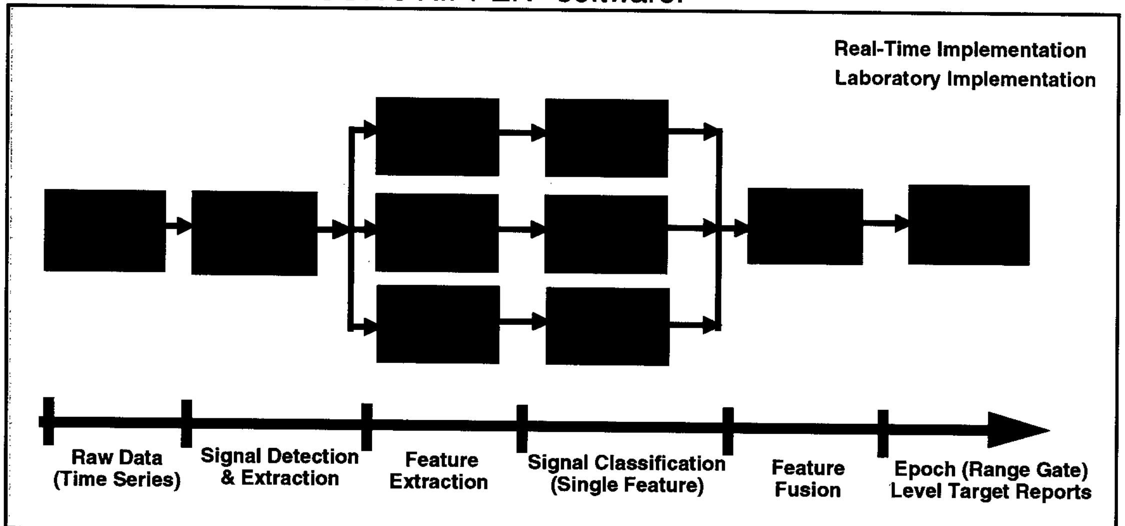


Figure 15.1 Biomimetic sonar signal and information processing functional block diagram

Initially, the analog sonar data is digitized with a 14-bit A/D board sampled at 1 MHz. Signal detection is then accomplished using a matched filter

algorithm. Next, the signal is localized within the range gate, extracted, and passed to the feature extraction stage. Feature extraction is achieved using three time-frequency representations (TFRs); a Short-Time Fourier Transform (STFT), a Morlet Wavelet Transform (MWT), and a dolphin-based Cochlear Model (CM). The STFT has been implemented in the real-time classification system (i.e. sea tests), and the WT and CM have been developed but only tested in laboratory experiments. These two-dimensional TFRs are classified using another neural network, thereby producing a synergistic classification system. In the final processing stage, an expert system performs epoch level (i.e. range gate) processing by formulating object classifications from multiple neural network outputs.

15.2 OBJECTIVES

The overall objective of this program was to develop a real-time, automated signal and information processing system to detect and classify buried and proud targets using an active broadband sonar. Another goal was to implement a signal processing model based on the dolphin cochlea and quantify its performance. The researchers sought to study how dolphins echolocate and identify objects, and then build a "machine" with comparable capabilities.

15.3 PROJECT ENVIRONMENT

ORINCON engineers worked in computer labs and offices located in Kailua, Hawaii. The dolphin work occurred at the Coconut Island facility of Hawaii Institute of Marine Biology off Kailua, Hawaii.

15.4 METHODOLOGY AND RESULTS

The general approach of ORINCON and HIMB was to understand and mimic the way that dolphins successfully find and classify buried targets in high noise and high reverberation environments. The research team constructed a sediment box testbed and placed small cylindrical test objects in it, as shown in Figure 15.2. They collected the sonar clicks that the dolphins used to identify the objects, and used this data to construct a computer model. A transducer known as the WAU 1 was used to project simulated dolphin pulses into the mud box and receive the resulting echoes (see Figure 15.3). They then implemented several unique signal and information processing algorithms and neural networks to detect and classify the objects.

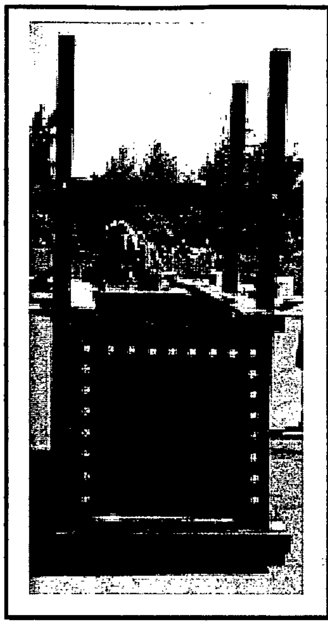


Figure 15.2a
Rear view of mud box

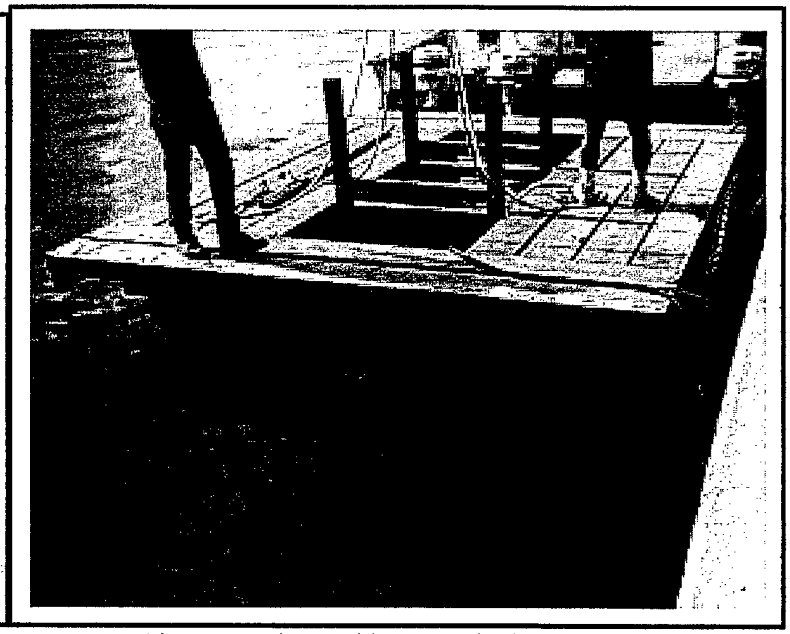


Figure 15.2b Mud box attached to support structure

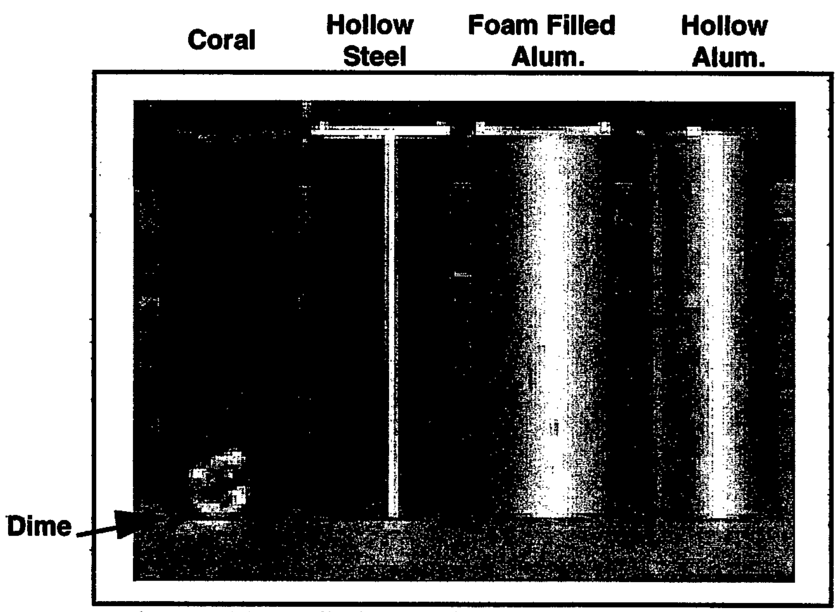


Figure 15.2c Cylinders used in biomimetic sonar tests

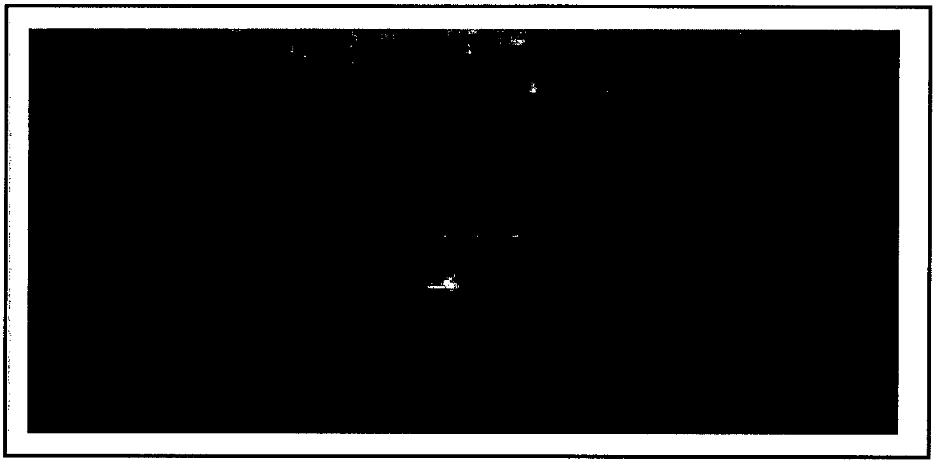


Figure 15.3 WAU 1 Transducer

During the initial phases of this program (FY93 - FY 94), a biomimetic signal and information processing system with feature extractors based on the Fast Fourier Transform (FFT) and AutoRegressive (AR) spectral estimator were effective at representing underwater echo returns from objects buried under bottom sediment. When a combination of neural networks, including feedforward and probabilistic networks was used, the researchers achieved a high level of correct classifications and a low false alarm rate. Then the acoustic environment was made more complex by adding clutter objects and by orienting the test objects at different aspects relative to the transducer.

While the baseline system was being tested, additional signal processing algorithms, such as a wavelet transform and dolphin cochlear model, were studied to determine their signal feature representation capabilities. Information resulting from ONR-funded experiments involving dolphin cochlea mechanics, including auditory filter size and shape, were modeled into a signal processing algorithm.

To precisely measure the system's ability to identify targets independent of aspect, controlled experiments were conducted within a water tank. Data was collected from four cylindrical targets at various aspects and used to train and test the system's neural networks, optimize existing algorithm parameters, and test new signal processing models (e.g. wavelet transform and cochlear model). Information gained during these experiments was transitioned into the real-time system and tested under operational conditions.

The results showed that the biomimetic signal and information processing system could effectively represent, detect, and classify echoes from objects buried under bottom sediment in a complex acoustic environment. Experimental constraints from the stationary transducer imply that even better performance could be obtained from movable transducers.

The third phase (FY95) involved the implementation of these signal processing algorithms in a real-time sonar system. First, a Lemmings bottom-crawling ROV was purchased and modified to support the installation of the existing active sonar, the WAU 1 transducer (see Figure 15.3). Signal processing algorithms were then ported to ONR-funded COTS hardware using ORINCON's RIPPEN® software. Figure 15.4 shows the real-time biomimetic display system. After successful system integration was achieved, moving transducer data collection and classification field experiments were conducted and system performance was quantified.

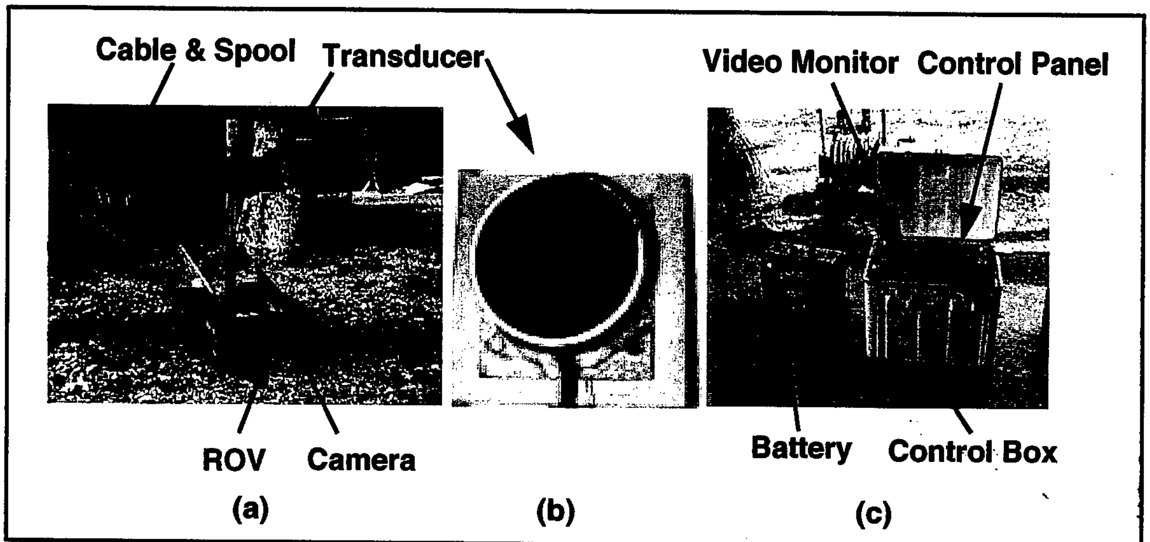


Figure 15.4 Lemmings ROV and associated components.
(a) vehicle (b) magnified photo of transducer (c) ROV control equipment

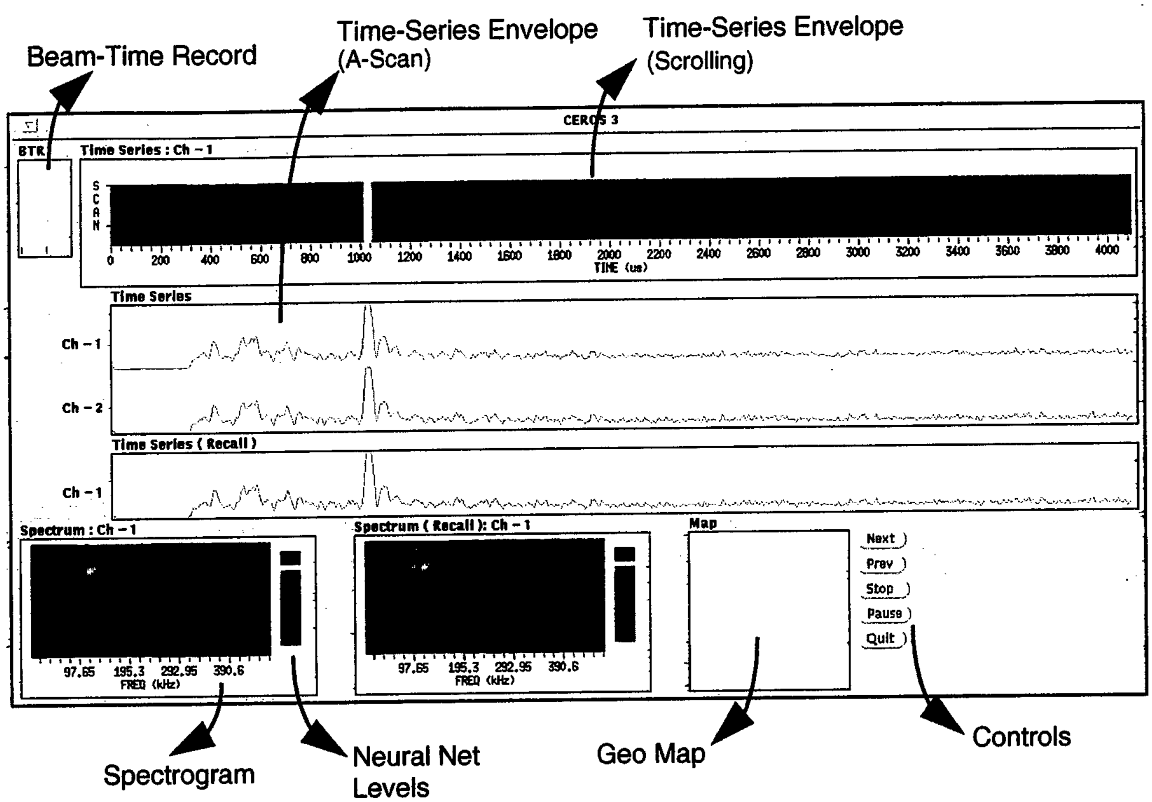


Figure 15.5 Real-time biomimetic display system

Experiments showed that a biomimetic signal- and information-processing system containing feature extractors based on Fast Fourier Transform (FFT) signal processing and AutoRegressive (AR) spectral estimation is effective at representing underwater echo returns for objects suspended in the water column and buried under bottom sediment. When a combination of neural networks, including feed-forward and probabilistic networks, is used in conjunction, a high level of correct classification performance with a corresponding low false-alarm rate can be achieved. Furthermore, when multiple successive echo classifications are integrated, overall system performance is improved substantially over single echo-classification results.

15.5 PRODUCTS

15.5.1 Commercial Products

No commercial products were developed.

15.5.2 Papers, Patents, and Disclosures

There were no invention disclosures or patents from this project. The numerous papers published are listed below.

Real-Time Sonar Classification of Proud and Buried Targets Using Dolphinlike Echolocation Signals. Shizumura, R.H., Au, W.W.L., Moons, G.C., Nachtigall, P.E., Roitblat, H.L., and Hicks, R.C.. Journal of the Acoustical Society of America, (1997) 102, 3152.

Aspect-Independent Sonar Recognition of Cylinders Using Dolphin-Like Signals. Au, W.W.L., Shizumura, R.H., Nachtigall, P.E., Hicks, R.C., Roitblat, H.L., and Moons, G.C.. Journal of the Acoustical Society of America, (1996) 100, 2643.

Classifying Buried Targets by Mimicking Dolphin Echolocation. Roitblat, H.L., Nachtigall, P.E., Au, W.W.L., Shizumura, R.H., and Moons, G.C.. Proceedings of the Conference on Theoretical and Computational Acoustics (1996).

Sonar Recognition of Targets Embedded in Sediment. Roitblat, H. L., Au, W. W. L., Nachtigall, P. E., Shizumura, R., and Moons, G.C.. Neural Networks, (1995) 8, 1263-1273.

Neural Network Modeling of A Dolphin's Sonar Discrimination Capabilities. Au, W.W.L., Andersen, L.N., Rasmussen, A.R., Roitblat, H.L., Nachtigall, P.E.. Journal of the Acoustical Society of America, (1995) 98, 43-50.

Echolocation and Imagery. Roitblat, H.L., Helweg, D.A., and Harley, H.E.. *in* Sensory Systems of Aquatic Mammals, R. Kastelein, J. Thomas, and P. Nachtigall (Eds.). (1995) pp.171-181, Woerden Publishers, The Netherlands.

Artificial Neural Network Modeling and Echolocation. Au, W.W.L., and Nachtigall, P.E.. *in* Sensory Systems of Aquatic Mammals, R. Kastelein, J. Thomas, and P. Nachtigall (Eds.). (1995) pp.183-201, Woerden Publishers, The Netherlands.

15.6 IMPACT

15.6.1 Job Creation

Because of this CEROS funding, ORINCON was able to create a full-time, permanent position for a technical intern who had been working with us on a part-time basis while earning his Master's degree from the University of Hawaii.

The FY94 funding supported over 4000 labor hours of five different engineering and technical positions at ORINCON. Of the total $652,685 awarded, $292,642 supported the subcontract to HIMB and $17,000 supported the subcontract to Dr. H.L. Roitblat.

The FY95 funding supported nearly 3000 labor hours of four different engineering and technical positions at ORINCON. Of the total $696,926 awarded, $299,997 supported the subcontract to HIMB, and nearly $25,000 went to independent consultants.

15.6.2 Business Development

As a result of this work, ORINCON developed an object-oriented engineering analysis display system. RIPPEN® passes its results to the display and, hence, to the operator. Like RIPPEN®, the display uses any COTS hardware.

15.6.3 Residual Benefits to Hawaii

Besides the creation of a full-time, permanent position for a University of Hawaii graduate, several other high tech jobs in the ORINCON Hawaii office were maintained.

15.6.4 Principal Investigator/Company Opinion

From a contract perspective, we have found CEROS very straightforward and easy to deal with. The requirements for participation and proposal submission are always clearly outlined. The individuals at CEROS are, without exception, approachable and receptive and, when a situation develops that may require a contract modification, we have found them to be flexible.

15.6.5 Impact on Principal Investigator/Company

As a result of this project, ORINCON is actively involved in sonar underwater classification which has led to other work with ONR and DARPA.

15.7 TRANSITION

Both ORINCON and HIMB received grants and contracts for work based on the CEROS funded projects.

16.0 Advanced Real-Time Signal Processor

ABSTRACT

ORINCON Hawaii, Inc. provided automated mission support tools to improve the tactical sonar system capabilities available to the Commander Submarine Forces Pacific (COMSUBPAC). Additional functional capabilities, requested by COMSUBPAC, were developed and integrated into the ARTS processor. The ARTS processor is a compact, powerful, real-time signal and information processing system that was developed by ORINCON Hawaii, Inc. using commercial, off-the-shelf (COTS) hardware. Interfaced to submarine sensor systems, ARTS provides full azimuth, real-time display and alert of passive acoustic signals for U.S. Navy submarines. Sea tests on a Pacific Fleet submarine resulted in very positive feedback. Follow-on funding in later years transitioned the product from water to the air for the Maritime Patrol Aircraft.

Contractor: ORINCON Hawaii, Inc.
970 N. Kalaheo Ave, Suite C-215
Kailua, HI 96734
phone: 808-254-1532

Principal Investigator: Mr. Gerald Moons
jerry@orinconhi.com

Contract Number:	Contract Amount:	Funding Year:
39571	$862,095	FY95
41487	$871,771	FY96

Start Date:	Completion Date:
September 1995	September 1996
September 1996	September 1997

16.1 BACKGROUND AND TECHNICAL DESCRIPTION

16.1.1 Background

The Antisubmarine Warfare Commander's Workstation and ARTS Processor meet an immediate need of the U.S. Navy to improve the defensive abilities of submarines by being able to detect, classify, and localize diesel-electric and nuclear submarines in littoral environments. It improves the ability of the Fleet to process large amounts of sonar data in "noisy" acoustic environments and reduce false alarms.

16.1.2 Technical Description

Using their proprietary signal and information processing scheme, the Real Time Interactive Programming and Processing Environment (RIPPEN®),

ORINCON Hawaii, Inc. (ORINCON) developed the Advanced Real-time Signal Processor (ARTS) with commercial, off-the-shelf (COTS) hardware. The ARTS processor is a compact, powerful, real-time signal and information processing system that provides automated target recognition capability to support tactical antisubmarine warfare (ASW) sensor operators. Interfaced to submarine sensor systems, ARTS provides full azimuth, real-time display and alert of passive acoustic signals for U.S. Navy submarines. The system can be deployed on a surface ship, submarine, or Maritime Patrol Aircraft to enhance automated, shallow-water ASW capability.

16.2 OBJECTIVES

ORINCON Hawaii proposed to develop a small, powerful signal processing system with flexible signal processing software that can be deployed on Pacific Fleet submarines or surface ships to provide an enhanced, automated shallow-water surveillance capability.

16.3 PROJECT ENVIRONMENT

The ORINCON Hawaii engineering offices are in a secure facility in Kailua, Hawaii. ORINCON personnel worked onboard the submarine to place the equipment into service and to train the enlisted users.

16.4 METHODOLOGY AND RESULTS

ORINCON developed a small, powerful signal processing system with flexible signal processing software that can be deployed on Pacific Fleet submarines or surface ships to provide an enhanced, automated shallow-water surveillance capability. This system will also be used by experts at ORINCON for development of advanced signal and information processing algorithms and analysis of shallow-water acoustic data. This project transitioned the ARPA advanced processing technology to the Fleet to address critical ASW problems.

ORINCON engineers worked closely with U.S. Naval personnel to develop and test the ARTS Processor, and the Navy is very satisfied with the result. During FY95, the ADM-3 multisensor fusion processor hardware was installed and demonstrated at CTF-12, and the ARTS operator machine interface was demonstrated. ORINCON also successfully demonstrated that ARTS meets development specifications for the Sonar Receiving Set AN/BQR-22A EC-15 and properly interfaces with the sonar set as required for full-scale demonstration on Fleet assets. The system interface with the sonar set was flawless. Additional tests demonstrated the processor's classification capabilities when tested against novel target signals from archived records. The system was installed on a Fleet asset for test and evaluation.

During FY96, the ARTS processor was successfully tested during a two-week sea trial. Initial operator evaluations were favorable. The Very Low

Frequency Type 1 Autodetector performance was successfully demonstrated for COMSUBPAC. An interface specification for the ARTS processor and the AFTAS TB23 array beamformer. The TB23 AFTAS/ARTS interface was successfully tested at NUWC, Newport, RI (April 97). All processes were displayed in real time using simulated data. Then the ARTS processor was successfully installed and tested aboard the USS Charlotte along with a complete spare parts suite for the system.

16.5 PRODUCTS

16.5.1 Commercial Products

The ARTS processor box is in great demand for U.S. Navy submarines and Maritime Patrol Aircraft. However, the demand is not backed fully by purchasing dollars.

16.5.2 Papers, Patents, and Disclosures

It is not appropriate to write papers or prepare patents about this DoD work. The system software is proprietary to ORINCON.

16.6 IMPACT

16.6.1 Job Creation

This project provided two permanent high technology jobs in Hawaii. Positions at ORINCON Hawaii stem the "brain drain" of Hawaii-educated engineers to the mainland.

16.6.2 Business Development

In August 1998, the Navy selected ORINCON's ARTS signal processing and display system as the principal signal processing scheme for the Advanced Processor Build Program. ORINCON Hawaii will enjoy substantial business growth as it fulfills a Navy-wide upgrade of sonar processors.

16.6.3 Residual Benefits to Hawaii

See 16.6.1 and 16.6.2.

16.6.4 Principal Investigator/Company Opinion

From a contract perspective, we have found CEROS very straightforward and easy to deal with. The requirements for participation and proposal submission are always clearly outlined. The individuals at CEROS are, without

exception, approachable and receptive and, when a situation develops that may require a contract modification, we have found them to be flexible.

16.6.5 Impact on Principal Investigator/Company

The CEROS program has allowed our company to hire additional employees locally, student interns from the University of Hawaii (some of which became full-time employees), and to develop new technologies that have expanded our capabilities as a high tech firm. We have also been able to further establish our professional ties with different military entities that became recipients of some of the technological advances that we have developed under CEROS programs. We feel strongly that the CEROS program is extremely beneficial to ocean sciences and high technology in Hawaii, provides benefits to the local economy by providing more high tech jobs, and helps to reduce the "brain drain" from Hawaii colleges and universities.

16.7 TRANSITION

CEROS funded follow-on ARTS projects in FY97 and FY98 for $500,000 and $373,000, respectively. ORINCON Hawaii is adapting the ARTS processor for use on Maritime Patrol Aircraft as well. See also 16.6.2. Another CEROS project, the Improved Acoustic Intercept Receiver, resulted from this project work. The ARTS project also led to work on the Acoustic Rapid COTS Insertion program as well as additional Full Spectrum Program tasking for the US Navy.

17.0 Submarine-Launched, Two-Way, Fiber Optics Linked Communications Buoy

ABSTRACT

This project addressed a generalized Navy need to provide capabilities to enable undersea platforms to communicate with war fighting commanders and Navy surface and air elements while remaining at operating depths. The need is for wide-band, two way communications between the submarine and surface or air elements. In this CEROS-supported effort, Orincon Hawaii and their subcontractor Sippican Corporation sought to demonstrate the feasibility of providing an optical fiber link to enable communications between a submarine operating at depth and an antenna buoy at the ocean surface. The effort included a feasibility study of optical fiber links, a spectral trade-off analysis to maximize performance, and a packaging study to show that the subsystem required could fit within the submarine signal ejector volume. The principal focus of the effort was to modify an AN/BRT-6 transmit antenna and demonstrate its radio frequency functionality. The antenna's functionality was demonstrated in June 97. The results of this effort point the way to a follow-on project to address critical submarine data processing and communication system requirements. Such a project was funded in the CEROS FY97 Core program.

Contractor: ORINCON Hawaii, Inc.
970 N. Kalaheo Ave, Suite C-215
Kailua, HI 96734
phone: 808-254-1532

Subcontractor:
Sippican, Inc.
Seven Barnabas Road
Marion, Massachusetts 02738
phone: 508-748-1160

Principal Investigator: Mr. Gerald Moons
jerry@orinconhi.com

Contract Number: 41941

Contract Amount: $160,000

Funding Year: FY96

Start Date: January 1997

Completion Date: September 1997

17.1 BACKGROUND AND TECHNICAL DESCRIPTION

17.1.1 Background

The Navy submarine community is eager to get on the information technology bandwagon and is seeking capabilities that will enable undersea platforms to communicate with war fighting commanders and other Navy elements on the surface or in the air while the submarine remains at operating depth. The ability to communicate large amounts of data between submarines and other Navy elements will give submarines a better overall view of the tactical situations using information from sensors on other platforms.

Currently available communications systems for submarines do not provide wide-band communications between submarines and other elements unless the submarine approaches the surface to use its mast antennas, an undesirable operation in most situations. The ability to communicate while remaining at operating depth is very limited.

Expendable, submarine-launched communications devices have demonstrated the capability for two-way communications over a wire link from a submarine operating at depth. However, the limited bandwidth of copper wire severely limits the operational utility of these submarine communication buoy systems. A fiber optic link in place of the copper wire solves the bandwidth problem. A conceptual drawing of the two-way fiber optics communications buoy is shown in Figure 17.1.

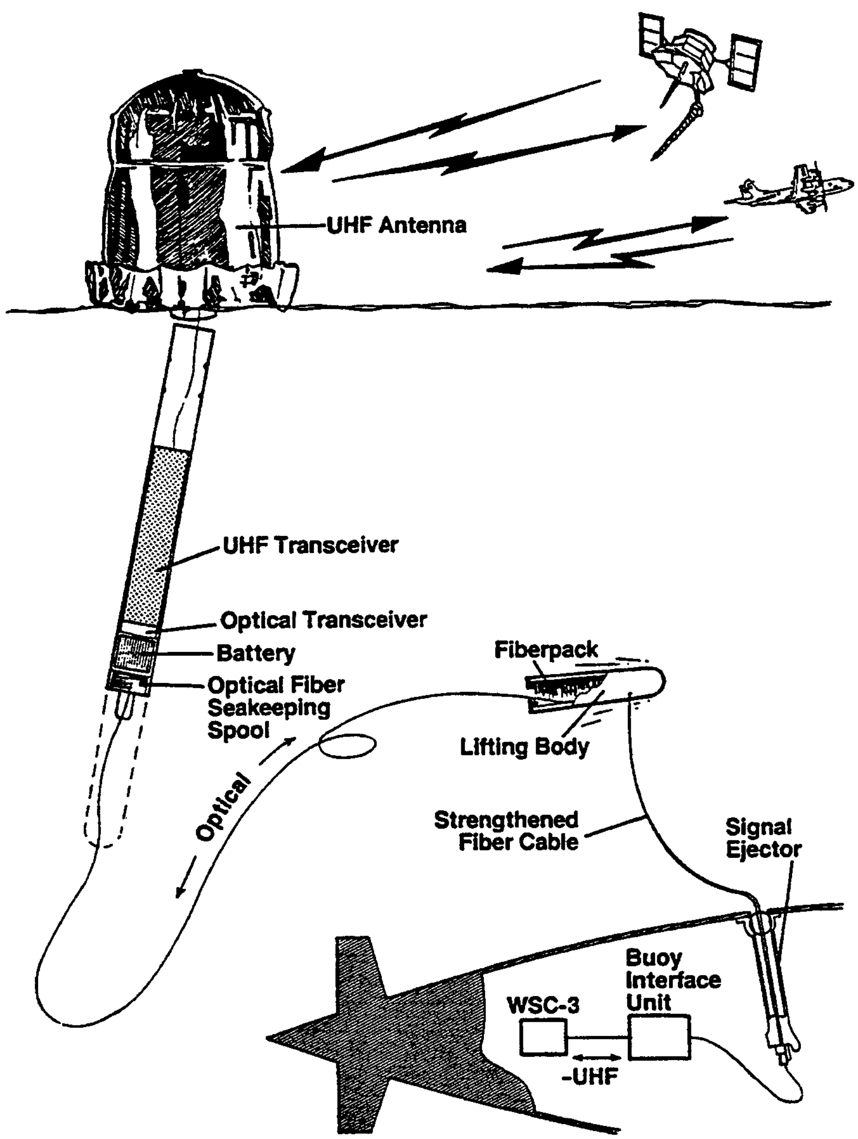


Figure 17.1 Conceptual UHF Fiber Optic Buoy System

17.1.2 Technical Description

The fiber-optic two-way communications buoy under design in this contract would be a modified AN/BRT-6 submarine-launched expendable transmitting buoy. The main components are a float, an antenna, electronics, electro (fiber) optics, battery, lifting body, and a seakeeping spool. The buoy antenna is a UHF transmitter, and an IF receiver that operate in the frequency ranges of 290 MHz to 320 MHz, and 240 MHz to 270 MHz, respectively.

17.2 OBJECTIVES

This feasibility study investigated a submarine-launched, two-way, fiber optic-linked communications buoy that will enable submarine commanders to exchange large amounts of data with other Navy elements while remaining at operating depth. The system must be launched from the submarine's signal ejector so the maximum dimensions are 3" diameter and 39" long.

17.3 PROJECT ENVIRONMENT

ORINCON engineers worked in their offices in Kailua, Hawaii, and Sippican engineers worked in their offices in Massachusetts. Engineers from both companies conducted the field tests at the Naval Undersea Warfare Center (NUWC) Arch Test Facility located in New London, Connecticut.

17.4 METHODOLOGY AND RESULTS

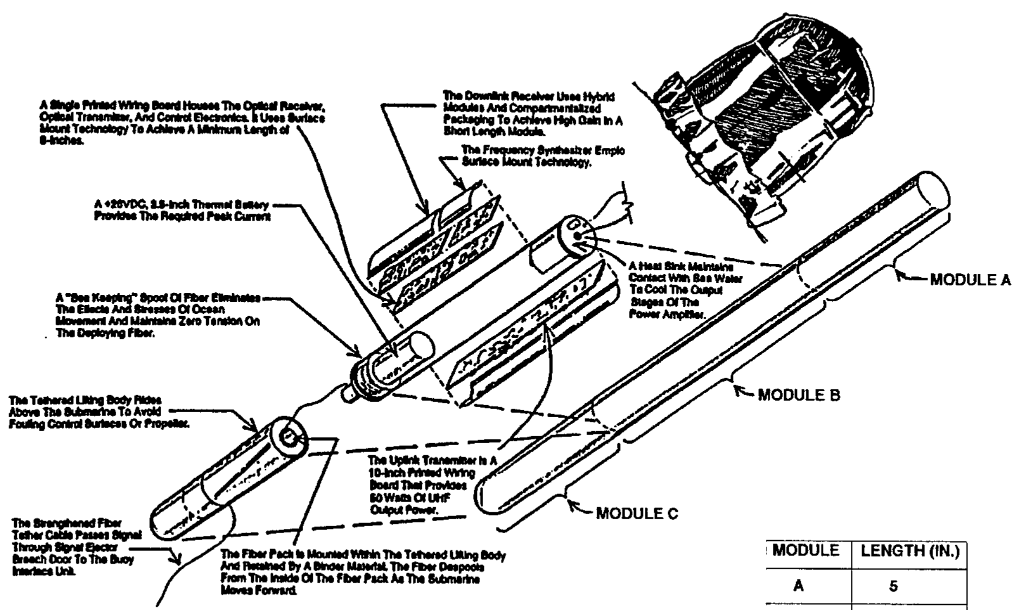
This contract supported a feasibility study and component selection for full-scale development, and a proof-of-concept test of antenna transmit/receive capability. ORINCON and subcontractor Sippican began with Sippican's expendable, submarine- launched, AN/BRT-6 antenna already in use for transmit only mode. A receive mode would be added for two-way communications, and the copper transmitting wire would be replaced with an optical fiber to increase bandwidth. These modifications would necessitate changes in the packaging, power supply, and other components.

The AN/BRT-6 buoy employs a UHF transmitter. The researchers compared UHF to baseband and IF frequencies for the fiber optic uplink and downlink. The baseband approach was eliminated due to large power and volume requirements. The critical difference between UHF and IF is the signal-to-noise ratio (SNR) at the buoy UHF receiver. The UHF uplink/IF downlink initially was chosen. However, the researchers first studied the antenna "as is" to determine if it could RF receive as well as transmit. Computer modeling indicated that the antenna could RF receive so field testing was conducted. The transmit band (290 MHz to 320 MHz) and the receive band (240MHz to 270 MHz) of the unmodified AN/BRT-6 antenna were measured at the Naval

Undersea Warfare Center (NUWC) Arch Test Facility located in New London, Connecticut. As expected, the antenna performed better in the transmit band than in the receive band. Still, even at receive frequencies the antenna yielded a gain of between -6dBIL to -10dBIL which should support line-of-sight communications with other vessels or aircraft in the area.

Optical fiber has three popular operational wavelength windows at 840, 1310, and 1550 nm, so ORINCON analyzed the characteristics of each wavelength to choose the best one for the fiber optics communications buoy. The 1310 nm wavelength showed lower fiber loss and dispersion, higher radiation resistance, better availability of optical devices at lower cost, lower fiber curvature bending losses, and a lower-cost laser diode. Production grade single mode optical fiber was chosen for its lower cost in this expendable application.

All components must fit into the space constraints of a submarine signal ejector with measurements of 3" diameter and 39" length. Based on Sippican's extensive analysis and testing, a simple, hollow, right circular cylinder shape was chosen for packing the optical fiber in the buoy housing. As shown in Figure 17.2, the overall packaging layout is modular: module A contains the float and antenna; module B contains the electronics, electro optics and battery; and module C contains the lifting body and seakeeping spool.



MODULE	LENGTH (IN.)
A	5
B	13.5
C	17.5

Figure 17.2 Buoy Packaging Layout

In summary, this feasibility study succeeded in the design of a two-way, fiber-optic communications buoy and initial testing of the AN/BRT-6 buoy

antenna. The researchers recommended several improvements that could be made to the antenna in future work. They also described how the two-way communications could be integrated into other submarine systems like ARTS Processor and the Situation Assessment System by ORINCON.

17.5 PRODUCTS

17.5.1 Commercial Products

This feasibility and design study did not result in a commercial product. Further development could result in a two-way communication buoy that would be used widely on submarines.

17.5.2 Papers, Patents, and Disclosures

No papers were published about this work. No patents or invention disclosures resulted from this contract.

17.6 IMPACT

17.6.1 Job Creation

This contract supported portions of several jobs at ORINCON in Hawaii. The bulk of the work was conducted by a senior engineer, an engineer, and the program manager. A technical writer and a technical typist also worked on this contract. The total labor hours was 608 hours. Around $72,000 of the total $160,000 went to the subcontractor, Sippican.

17.6.2 Business Development

ORINCON pursued and received CEROS funding in subsequent years to continue development of this product.

17.6.3 Residual Benefits to Hawaii

High-tech jobs in Hawaii were maintained. A working relationship with a leading Hawaii R&D company was formed with Sippican, a worldwide leader in oceanographic instrumentation and ASW.

17.6.4 Principal Investigator/Company Opinion

From a contract perspective, we have found CEROS very straightforward and easy to deal with. The requirements for participation and proposal submission are always clearly outlined. The individuals at CEROS are, without exception, approachable and receptive and, when a situation develops that may require a contract modification, we have found them to be flexible.

17.6.5 Impact on Principal Investigator/Company

The CEROS program has allowed our company to hire additional employees locally, student interns from the University of Hawaii (some of which became full-time employees), and to develop new technologies which have expanded our capabilities as a high tech firm. We have also been able to further establish our professional ties with different military entities who became recipients of some of the technological advances that we have developed under CEROS programs. We feel strongly that the CEROS program is extremely beneficial to ocean sciences and high technology in Hawaii, provides benefits to the local economy by providing more high tech jobs, and helps to reduce the "brain drain" from Hawaii colleges and universities.

17.7 TRANSITION

CEROS funded follow-on work in FY97 for $200,000.

18.0 Tri-strut Ship Research, Development and Test Model: MidFoil

ABSTRACT

Pacific Marine & Supply Co. combined funds from CEROS, the Hawaii Electric Vehicle Development Program, and MARITECH of DARPA to design, test, and build a manned model of a new ship design called "MidFoil." Rather than a traditional v-hull or even a catamaran-style SWATH, the MidFoil has a foil-shaped body placed amidships to provide displacement. CEROS supported the computerized design and testing with computational fluid dynamics, small-scale physical model tests, and construction of the unique foil for the 65-foot manned model. The 50 ton vessel was launched in Honolulu Harbor in January 1998 and ran successfully. The vessel exhibits an extremely smooth, stable ride even in rough seas and at speeds over 20 knots. The design can be scaled up to 10,000 tons for various DoD applications and commercial applications like shipping and ferries. Results have direct application to ARPA and ONR advanced fast ship programs. Benefits from the Tri-Strut effort were applied to the Pacific Marine SLICE program.

Contractor: Pacific Marine & Supply Co, Inc.
841 Bishop Street, Suite 1880
Honolulu, HI 96734
phone: 808-531-7001

Principal Investigator: Mr. Steven Loui
pacmar@aloha.net

Contract Number:	Contract Amount:	Funding Year:
38242	$365,400	FY94
39797	$780,000	FY95

Start Date:	Completion Date:
October 1994	September 1995
November 1995	July 1998

18.1 BACKGROUND AND TECHNICAL DESCRIPTION

18.1.1 Background

The DoD needs fast, smooth, shallow-draft ships that can operate in high sea states in the open ocean and in shallow coastal areas.

18.1.2 Technical Description

The MidFoil is a 65 foot working ship model of a revolutionary hull design. Rather than a traditional v-hull or even a catamaran-style SWATH, the MidFoil has a foil-shaped body placed amidships to provide displacement.

18.2 OBJECTIVES

Pacific Marine sought to design, test, and prototype a new ship hull form that can travel at high speeds and operate in high sea states. Based on indications and results from other efforts involving advanced, high-speed vessels like SWATH and SLICE, Pacific Marine proposed to develop and test an improved small displacement, low waterplane area ship (LOWASH) hull form called Tri-Strut. The Tri-Strut ship technology seeks to reduce the drag associated with small waterplane area twin hull (SWATH) ships by replacing the longitudinal hulls and struts with a single forward strut/canard configuration in conjunction with a submerged midship foil that resembles an aircraft wing in cross section.

18.3 PROJECT ENVIRONMENT

Pacific Marine design offices and ship-building yard are located at Pier 41 in Honolulu.

18.4 METHODOLOGY AND RESULTS

Pacific Marine carried out an extensive evaluation of scaled drag components from non-conventional hull forms (e.g. SLICE). Based on studies of 3 major computational fluid dynamics programs, Pacific Marine reconciled drag component definitions to allow direct cross-model and cross-analysis comparisons of results. Computerized analysis of design options yielded a select suite of options for model testing. Model tests at David Taylor and U. S. Naval Academy test tanks showed good conformance with predictions and very low drag for the hull. Pacific Marine reported that Leading Edge Suction generated at speed significantly reduced pressure drag on the hull form. "Optimization of this benefit could result in further improvements in efficiency of the baseline design and offer the potential of very high speed designs (*e.g.* in excess of 100 knots)." Model tests at the Naval Academy verified the Computerized Fluid Dynamics predictions concerning head sea conditions and wavemaking. Additional model testing conducted in Norway at the Marintek facility indicated some dynamic instabilities that were corrected. Tow model tests indicated that a design with "sponriggers" and no forward foil would be possible. In follow-on years, Pacific Marine fabricated and constructed the MidFoil at its Honolulu ship-building yard. Figure 18.1 is a photograph of the partially completed MidFoil being lifted into the water at Pacific Marine's Honolulu shipyard. The namesake midfoil is clearly visible.

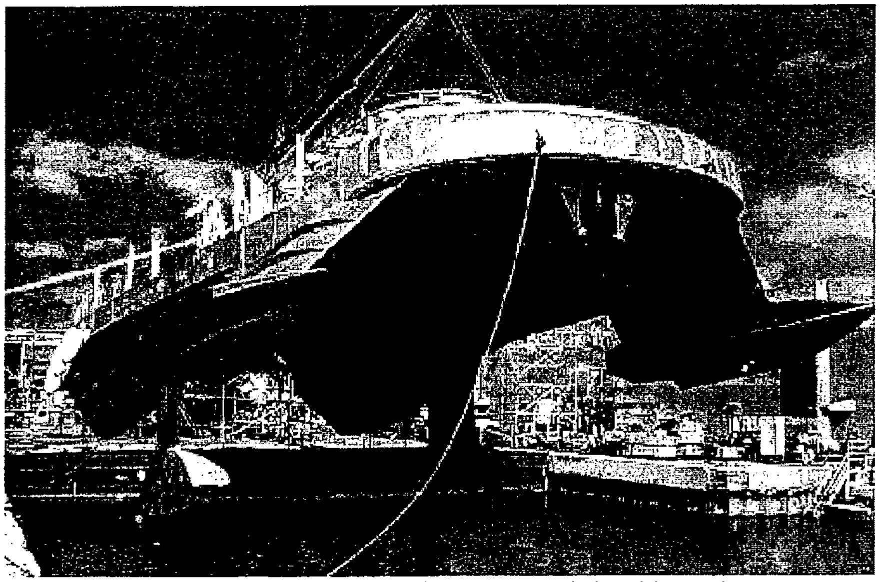


Figure 18.1 Midfoil at Honolulu Shipyard

The MidFoil appears to be a "best combination" of SWATH and hydrofoil technologies. Small waterplane area ships and hydrofoils have superior motions, i.e. a smoother, more stable ride than more traditional hull designs. SWATHs' drawback has been a limitation in speed/power performance. Hydrofoils have excellent speed/power performance, but generally only at one speed or a narrow band of speeds because hydrofoil lift forces vary as the square of the vessel speed.

The MidFoil is a hybrid of the SWATH and the hydrofoil support concepts. MidFoil uses a submerged, low-drag foil similar to an airplane wing that is placed amidships. Because MidFoil is a displacement ship there is no "speed band" as occurs with a hydrofoil supported by dynamic lift. This results in a vessel with excellent performance at all speeds, and excellent motions at all speeds. The buoyantly-supported MidFoil is not a hydrofoil because by definition hydrofoils are supported dynamically. However, water circulation over the MidFoil's main foil counteracts sinking and provides other beneficial free surface interactions unobtainable by a SWATH or other small waterplane hull forms.

MidFoil promises significant improvements over other existing hull forms due to reduced resistance (less wetted surface area, less wave-making drag, and less appendage drag), improved seakeeping, increased propulsive efficiency, better hydrostatic and hydrodynamic stability, and higher transport efficiency.

18.5 PRODUCTS

18.5.1 Commercial Products

Pacific Marine may place the MidFoil into the tourist adventure market, probably around Kauai, when the vessel receives the necessary Coast Guard

certifications. The MidFoil will be used to test other lifting bodies (the Gornstein body) in place of the foil. A scaled-up version of the MidFoil was proposed for a commercial ferry, and for the Navy's fast ship program. No commercial sales have resulted as of the time of this writing. Figure 18.2 shows a photograph of the MidFoil underway in the Pacific Ocean off Waikiki.

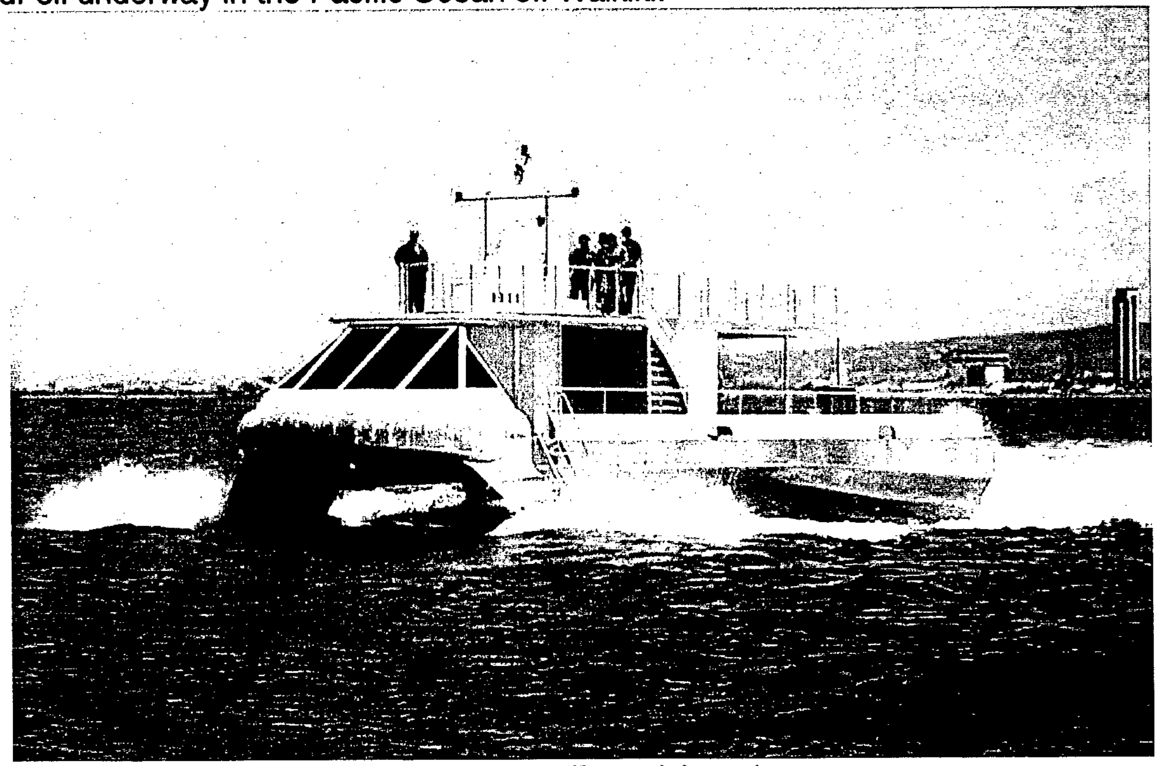


Figure 18.2 Midfoil underway off Honolulu Harbor

18.5.2 Papers, Patents, and Disclosures

No papers were published. Pacific Marine received U.S. Patent number 5,645,008, for "Mid Foil SWAS" on July 8, 1997. At least two other patents are pending from follow-on work.

18.6 IMPACT

18.6.1 Job Creation

The MidFoil project led to the creation of ten permanent jobs at Pacific Marine. Six of these are technical positions, including four design and engineering positions, and two construction management positions. Due to the cutting edge status of this project, Pacific Marine was able to lure top engineers from major mainland companies as well as hire local graduates. Four other ship building production jobs were also created. All positions continue to be sustained by subsequent contracts emerging from this work.

In FY94, engineers, naval architects, project director, and clerical support totaled 2,000 labor hours. In FY95, Pacific Marine's shipbuilding labor was funded for 2,000 hours and engineer design was funded for 1340 hours.

18.6.2 Business Development

Pacific Marine continues to design and build new ship designs, to pursue funding from ONR and congressional channels, and to create markets for its ships in the ferry and excursion boat markets.

18.6.3 Residual Benefits to Hawaii

Pacific Marine is a world leader in pioneering ship designs that bring visibility to the cutting edge technology being developed in Hawaii, as well as providing jobs and necessary DoD platform designs. This project helped to upgrade production techniques and labor force skills at Hawaii and mainland shipyards.

18.6.4 Principal Investigator/Company Opinion

CEROS is a very cost-effective, efficient, and responsive program. The close interaction with the CEROS staff, excellent communication, and coordination allows the contractor to spend more time and money on work and less on travel and reporting. It is a great advantage to have a program office located locally, and to be a smaller program.

18.6.5 Impact on Principal Investigator/Company

The credibility gained from work on MidFoil has resulted in several follow-on research contracts from ONR, DARPA and other agencies that total over $8 million. Also, Pacific Marine recently filed patent applications that it expects will lead to at least two more patents which builds the company's net worth in intellectual property.

18.7 TRANSITION

CEROS provided follow-on funding in FY97, 98 and 99 in the amounts of $654,000, $300,000, and $800,000. Results have direct application to ARPA and ONR advanced fast ship programs. Benefits from the Tri-Strut effort were applied to the Pacific Marine SLICE program. Other follow-on contracts are the $600,000 design contract for ONR for fast patrol craft, and a $70,000 SBIR from NAVSEA for future mine warfare craft called MCM(X).

19.0 Development of a Technique to Identify Pollutant Sources and Impacts in Coastal and Oceanic Waters

ABSTRACT

Sea Engineering, Inc. with subcontractors from CalTech studied whether Inductively Coupled Plasma Mass Spectrometry (ICP-MS) could be used to measure freshwater discharges into saline coastal waters in Hawaii. Although previous work had applied ICP-MS to fresh and slightly saline waters, this was the first trial of the technique on samples from fully saline or oceanic waters. The ICP-MS technique is capable of identifying elements and suites of elements in discharge sources. However the unique spectral "fingerprints" that have been identified for mainland streams and rivers were not found in stream samples from O'ahu. Furthermore, the low concentrations of elements in the O'ahu discharges were masked by high concentration of "salt" ions in saline samples. Differences in rare earth elements between freshwater and saline samples provided a "reverse tracer" that enabled Sea Engineering to develop an accurate measure of dilution to trace effluent discharge plumes in the ocean. The project provided important fundamental data for applying the powerful ICP-MS technique to oceanic environments.

Contractor: Sea Engineering, Inc.
Makai Research Pier
Waimanalo, HI 96795
phone: 808-259-7966

Subcontractor: John List
California Institute of Technology
Pasadena, California

Principal Investigator: Mr. Robert Rocheleau
seaeng@lava.net

Contract Number: 38103

Contract Amount: $146,000

Funding Year FY94

Start Date: November 1994

Completion Date: July 1996

19.1 BACKGROUND AND TECHNICAL DESCRIPTION

19.1.1 Background

Pollution in coastal waters is an environmental, regulatory, and economic problem. Determination of the source of the pollution from various point and non-point sources is key for legal and monetary responsibility. However, it is often difficult to determine the sources, as evidenced by a nine million dollar Mamala Bay Study that did not answer an environmental impact claim by the Sierra Club Legal Defense Fund against the City and County of Honolulu for the effects of two municipal sewer outfalls. Similarly, is the nearshore water quality degradation in Kailua Bay due to a municipal sewer outfall or due to storm water discharges from streams? While studies by the University of Hawaii indicated that the stream discharges are causing the problem, the public's perception is that the municipal outfall is the culprit.

ICP-MS can make extremely accurate measurements of trace elements in water samples and therefore may be used to determine the behavior of elements in discharges into water bodies. ICP-MS has been used for the determination of elemental concentrations in fresh water for several years, but has not been used in sea water samples. A given water body may have an elemental fingerprint that can be traced into a larger body of water with which it mixes. This can be used to determine which sources are contributing which elements. In the example above, if ICP-MS can tell the difference between the municipal outfall and the stream outfalls, then it may be used to identify the source of the water quality degradation in Kailua Bay.

Prior to this contract ICP-MS had been used in freshwater streams and in a low salinity estuary, the San Francisco Bay. It had not been attempted in fully saline oceanic waters like the Pacific Ocean nearshore to Hawaii.

19.1.2 Technical Description

Inductively coupled plasma-mass spectrometry (ICP-MS) was first introduced commercially in 1983 as a method for rapid, highly accurate multi-elemental analysis. ICP-MS consists of two separate operations, the creation of a plasma, and the analysis of that plasma. The plasma consists of ionized atoms from a water sample of interest. After its creation, the plasma passes through an interface between the plasma torch and a quadrupole mass spectrometer. The mass spectrometer operates as a filter; along its axis, a path exists for ions of only one mass-to-charge ration. ICP-MS allows for rapid and accurate determination of the concentrations of many elements in a small volume of sample. It is relatively low-cost, and the detection limits for most elements are much lower than other analytical methods (see Figure 19.1, ICP-MS Detection Limits). The fundamental basis of this study is the ability of ICP-MS to measure elemental concentrations in water samples with exceptional accuracy.

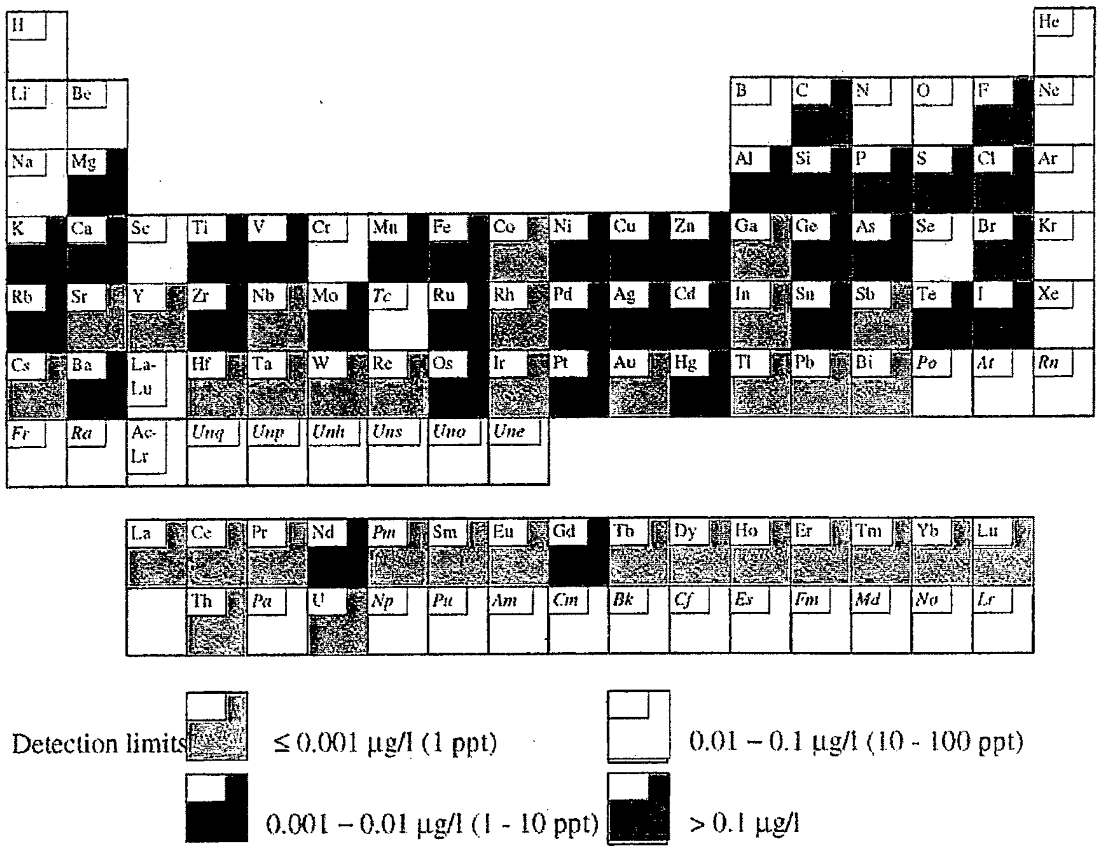


Figure 19.1 ICP-MS Detection Limits

19.2 OBJECTIVES

This work will develop, prove and demonstrate the inductively coupled plasma mass spectrometry (ICP-MS) technique in open coastal marine environments. Specific aims are to (1) identify specific elemental "fingerprints" for pollution sources, (2) apply ICP-MS technique to high salinity samples, (3) define temporal variability of discharges in study areas, and (4) standardize techniques and develop a database.

19.3 PROJECT ENVIRONMENT

The contractors collected water samples at various sites around Oahu as detailed in the next section. Laboratory analyses were conducted in chemistry labs at the California Institute of Technology (CalTech).

19.4 METHODOLOGY AND RESULTS

This project sought to determine if ICP-MS would work in seawater. The critical challenges was whether the high salinity would interfere with ICP-MS, and if so, could it be overcome? The project would search for distinct tracers for discharges into the ocean from domestic sewage, stream and storm water discharges, industrial discharges, and other sources. Then the researchers would determine if the tracers could be used to measure the relative inputs into the bay or ocean area of interest.

Three types of discharges into fully saline coastal waters were selected for this project: domestic sewage, perennial stream flow, and storm water runoff. The domestic sewage samples were taken from the Waianae Ocean Outfall, one of Oahu's four municipal outfalls. The perennial stream discharge samples were taken from the Pearl Harbor drainage basin. Eight streams enter the harbor, as shown on Figure 19.2. Halawa, Kalauao, Waiawa, Waikele, and Waimalu are perennial; Aiea, Honouliuli and Waiau are intermittent. Waikele stream has the largest flow of all the streams studied. Although Pearl Harbor receives only 20 to 30 inches of rain per year, the rainfall at the heads of the streams ranges up to 250 inches per year. Runoff to Pearl Harbor drains forest, agricultural, commercial, industrial, military, and residential lands.

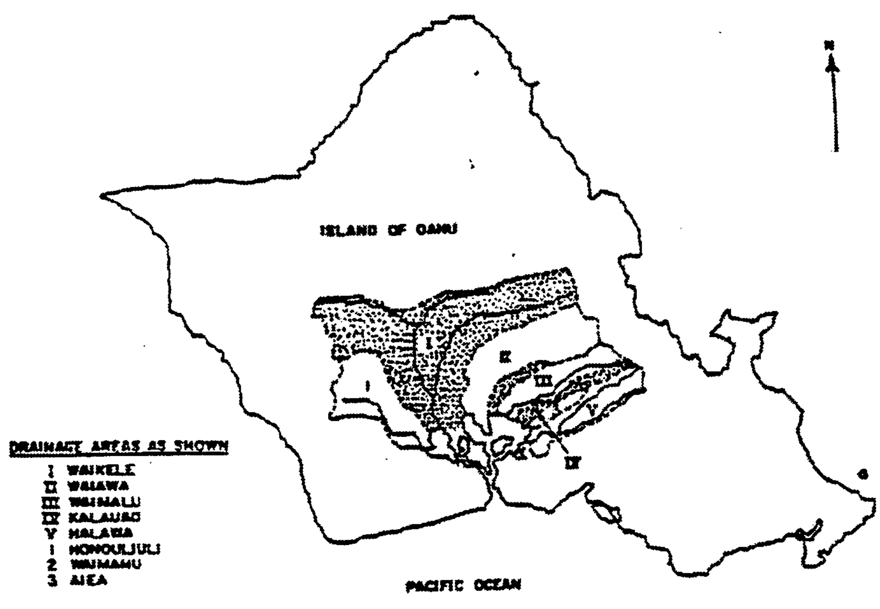


Figure 19.2 Pearl Harbor Drainage Basin

The storm water runoff samples were taken from the Ala Wai Canal. The Ala Wai Canal, shown in Figure 19.3, is a two-mile long man-made waterway,

constructed between 1921 and 1928, that drains three watersheds, Manoa-Palolo, Makiki, and Kapahulu. Approximately 60% of the watershed is urban, with a dense road network and high automobile traffic. Under normal conditions, the canal has relatively low fresh water input, and tidal flushing is the primary circulation mechanism.

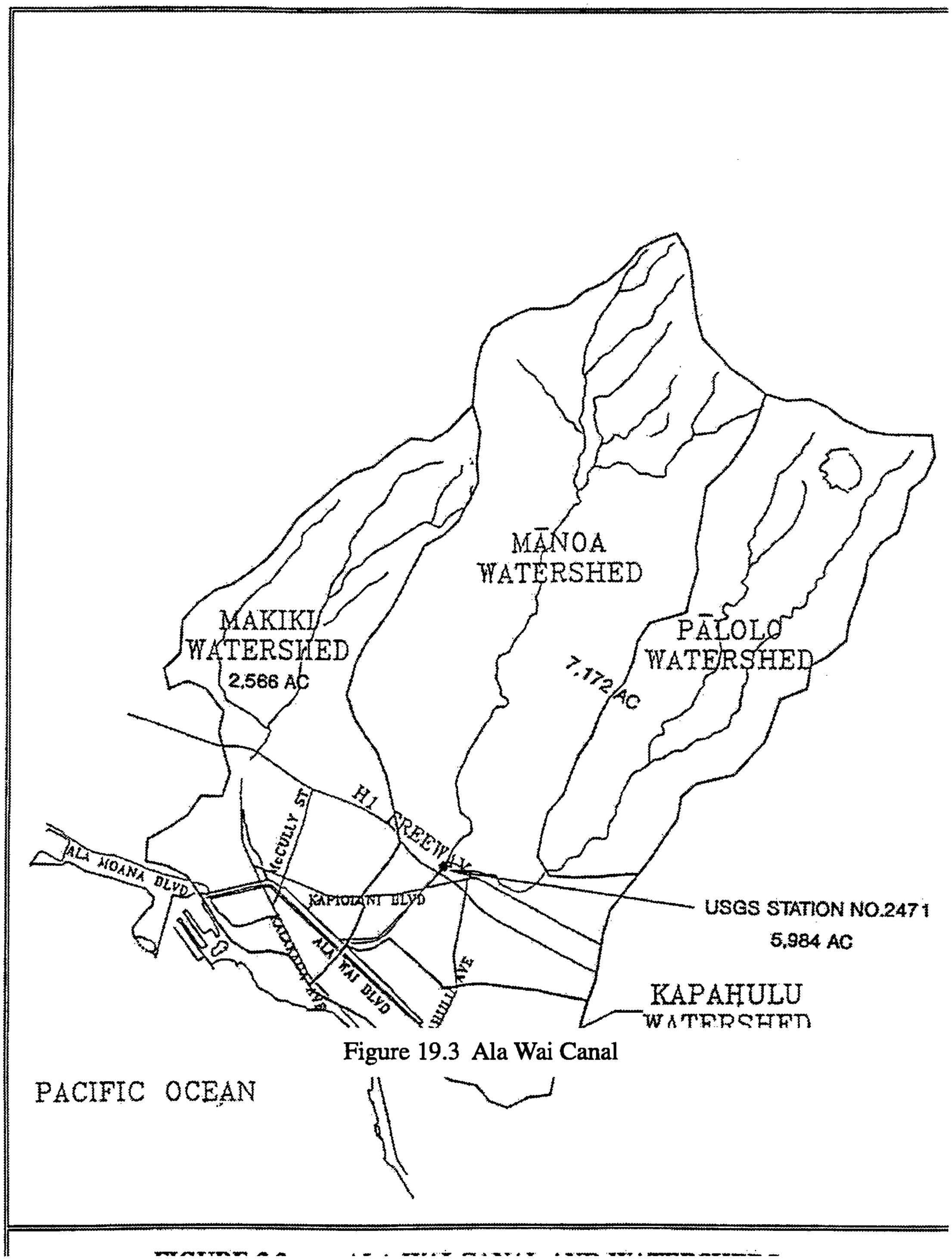


Figure 19.3 Ala Wai Canal

During infrequent heavy rains, the freshwater discharge increases to as much as 2,000,000 cubic feet (and rarely to 50,000,000) of runoff over a few days. The 1996 Mamala Bay study concluded that during heavy rainfall, the Ala Wai Canal contributed large concentrations of fecal coliforms to the bay, and was a major source of contamination to Waikiki Beaches.

Fresh water sampling was conducted at the streams discharging into Pearl Harbor, the stream input into the Ala Wai Canal, and the Waianae Wastewater Treatment Plant. Samples from the streams entering Pearl Harbor and from the Wai'anae Treatment Plant were collected biweekly, for a total of 23 times, to determine if there was a unique spectral "fingerprint" for each discharge, and to address the question of temporal variability. Only surface samples were taken from the relatively shallow streams, and the water column off the Wai'anae Plant was sampled at 20, 40, 65, and 90 foot depths at each station.

The main technical obstacle arose from the analysis of saltwater samples using ICP-MS. Several problems occurred like "salting up" of cones and lenses within the instrument, detector saturation, and viscosity differences between fresh and saltwater samples. There may also be chemical effects because the saltwater matrix is so rich in major ions, see Table 19.1. Additionally, concentrations of many elements in seawater are several orders of magnitude higher than in freshwater.

Table 19.1 Major Ions in Seawater

Cations	Abundance (‰ w/w)	Anions	Abundance (‰ w/w)
Na^+	10.556	Cl^-	18.980
Mg^{2+}	1.272	SO_4^{2-}	2.649
Ca^{2+}	0.400	HCO_3^-	0.140
K^+	0.380	Br^-	0.065
Sr^{2+}	0.013	$H_2BO_3^-$	0.026
		F^-	0.001

Over 250 samples from the streams draining into Pearl Harbor, the Ala Wai Canal, and Inoa'ole Stream in Waimanalo were collected and analyzed during the study. The ICP-MS analysis of these samples revealed that the elemental signatures of these streams were not distinct from each other, that is, the streams have no unique spectral "fingerprint." This is in sharp contrast to findings from the mainland where rivers show distinct elemental signatures. It seems that the relative uniformity of Hawaii's surface waters strongly precludes the identification of unique tracers. The homogeneity of the streams is likely due to the relatively uniform geologic composition of the island and the small

drainage area. Elemental analysis of the samples also indicated that the fresh water sources on Oahu do not contain elements in high enough concentrations to enable trading the water discharged into the ocean.

Several techniques were tested to make ICP-MS work for the saltwater samples. Only a few elements, rubidium (Rb), strontium (Sr), and uranium (U) could be measured accurately using a standard addition technique. This was the only technique that produced usable results. Because these three elements have natural concentrations that are higher in seawater than in freshwater, when a lower concentration in seawater occurs it means a greater influx of freshwater and subsequent dilution of the concentration in seawater. Thus, these elements act as "reverse tracers" and indicate the amount of dilution by freshwater, and the reverse tracer method was selected during this project. Elemental "fingerprints" were established for freshwater source streams but they were so similar that they could not be used to differentiate them. Concentrations of Rb, Sr, and U were used to track the discharges of the Ala Wai Canal into the ocean, and the Waikele Stream into Pearl Harbor.

Given the deficit of suitable tracer elements in the discharge sources studied, various elements were investigated for possible use as added tracers. There are numerous constraints on the selection of an appropriate tracer. It must be non-toxic to marine species, inexpensive, not form flocculents that precipitate in seawater, have a low background concentration in seawater, and be detectable by ICP-MS at relatively low concentrations in a saline background. Lanthanum chloride was chosen and injected into the Waianae Outfall prior to sampling on one occasion. Inconsistent results indicate that additional research is required to optimize this technique. However, tracer addition works extremely well in freshwater and the researchers planned to continue this work. The CalTech subcontractor predicted that results from the Hawaii work would significantly benefit their ongoing work in the San Francisco Bay area supported by other funding.

In summary, Sea Engineering and Cal Tech found that the low concentrations of elements in the O'ahu discharges were masked by high concentration of "salt" ions in saline samples. Differences in rare earth elements between freshwater and saline samples provided a "reverse tracer", however, that enabled Sea Engineering to develop an accurate measure of dilution and, thus, trace effluent discharge plumes in the ocean. The project provided important fundamental data for applying the powerful ICP-MS technique to oceanic environments.

19.5 PRODUCTS

19.5.1 Commercial Products

No commercial products resulted from this proof-of-concept study.

19.5.2 Papers, Patents, and Disclosures

There were no invention disclosures or patents from this project. One paper was published and the reference is listed below.

Tracing Discharges in Ocean Environments Using a Rare Earth Tracer. Susan C. Paulsen, E. John List, Robert Y. Rocheleau, and Theodore S. Durland. Water for a Changing Global Community XXVII IAHR Congress, San Francisco, 10-15 August 1997.

19.6 IMPACT

19.6.1 Job Creation

Over $66,000 supported labor at Sea Engineering where a project engineer, ocean engineer, and marine technician worked a total of 120 days on this contract. This contract helped create one new position at Sea Engineering that has been maintained largely due to work based on the subbottom profiler developed under other CEROS contracts. Over $46,000 supported jobs at CalTech where a principal investigator, graduate researcher, and undergraduate assistant worked a total of 172 days on this contract.

19.6.2 Business Development

To develop business from this contract, Sea Engineering contributed to a paper presented by John List at a 1996 ASCE Conference, "Water for a Changing Global Community." Sea Engineering has maintained a working relationship with John List from CalTech and they have submitted several proposals with him for engineering projects.

19.6.3 Residual Benefits to Hawaii

Although the ICP-MS project was not totally successful, Sea Engineering maintained a working relationship with John List, the P.I. from CalTech, and they are currently involved in an engineering project with him.

19.6.4 Principal Investigator/Company Opinion

Sea Engineering believes that CEROS is a valuable resource for Hawaii. Most importantly, it has provided a merit-based, competitive means of funding research projects to address Hawaii's special needs. CEROS is doing an excellent job, and we have no suggestions for improvements at this time.

19.6.5 Impact on Principal Investigator/Company

This CEROS contract had a beneficial impact on the PIs and the company by providing unique capabilities and experience, including the development of

relationships with individuals and organizations that they would not ordinarily have dealt with. This has widened their horizons, leading to increased opportunities for the company, including the ability to export their services overseas.

19.7 TRANSITION

No further CEROS funding was awarded to this project. Sea Engineering and John List of the California Institute of Technology continue to collaborate on various engineering proposals. CalTech was able to apply the Hawaii experience to its ongoing work in the San Francisco Bay.

20.0 Development of a Broad-band FM Sub-bottom Profiler for Seafloor Imaging and Sediment Classification

ABSTRACT

This work demonstrated the function and utility of the broadband FM sub-bottom profiler developed with FY93 CEROS support. Sea Engineering developed and tested a state-of-the-art broadband, sub-bottom acoustic profiling system for shallow water surveys. The system provides rapid and accurate bottom classification and characterization. It is uniquely capable of distinguishing consolidated and unconsolidated coral sands, as demonstrated during field tests off Waikiki Beach. The contractors developed expert system classification rules and interactive interface for the subbottom profiler system. The classification algorithms were upgraded using fuzzy logic rules. The profiler was delivered from Florida, assembled and tested in four diverse areas; sand deposits not previously imaged were identified. This development extends technology applied at NUSC and for NRL Benthic Boundary Layer program. Sea Engineering seems to be developing a "breakthrough" technological tool for commercial application in the Pacific. In May 1996, the Geological Survey of the United States Department of the Interior contracted with Sea Engineering to survey sediment deposits in Kailua Bay, O'ahu using the profiler. The survey's chief scientist acknowledged the Sea Engineering system as providing excellent records to support deposit volume, composition, and history estimates.

Contractor: Sea Engineering, Inc.
Makai Research Pier
Waimanalo, HI 96795
phone: 808-259-7966

Subcontractor: Precision Signal, Inc.
450 N.E. 20th Street, Suite 113
Boca Raton, FL 33431

Principal Investigator: Mr. Robert Rocheleau
seaeng@lava.net

Contract Number:	Contract Amount:	Funding Year
38109	$223,870	FY94

Start Date:	Completion Date:
November 1994	April 1996

20.1 BACKGROUND AND TECHNICAL DESCRIPTION

20.1.1 Background

Hawaii has an acute need to locate and map offshore sand sources for construction and beach nourishment. Existing sub-bottom profilers work poorly in the calcareous environment of Hawaii and so the surveys were inaccurate. This new sub-bottom profiler will allow accurate maps of offshore sand. The DoD requires accurate maps of the seafloor and its acoustic properties. This sub-bottom profiler is also an important step for the development of a system for detecting and locating buried ordnance. Other applications include dredging

surveys, foundation investigations for offshore structures, directional drilling planning, geohazards surveys, and pipeline and cable locations.

Sea Engineering and Precision Signal began this project under a CEROS FY93 contract that involved the design, development, and testing in Hawaii of a prototype vehicle containing variable array geometries. This prototype was deployed to establish the frequency bands, and receiving and transmitting aperture sizes for imaging and classifying sands overlying a coral basement. The FY94 contract described in this report completes the development of the subbottom profiler, including assembly of an optimized profiler design based on the FY93 results, coding and addition of state-of-the-art sediment classifications techniques, and field testing with the profiler and sediment classification techniques.

20.1.2 Technical Description

The model 0408 X-Star sub-bottom profiler is a planar sonar fish for mapping the ocean bottom and upper sediment layers in calcareous environments. The completed sonar system has an operating band of 400 Hz to 10 kHz. The wide frequency range provides sufficient penetration into thick deposits to detect basement and also allows resolution of thin stratigraphic units. A large 1.5 X 1.5 meter planar receiving aperture and acoustic baffle greatly reduces scattering noise from the sediments and sea surface. An innovative V-wing configuration in the tow vehicle minimizes the target strength of the vehicle and reduces multiples. Figure 20.1 shows a schematic of the device.

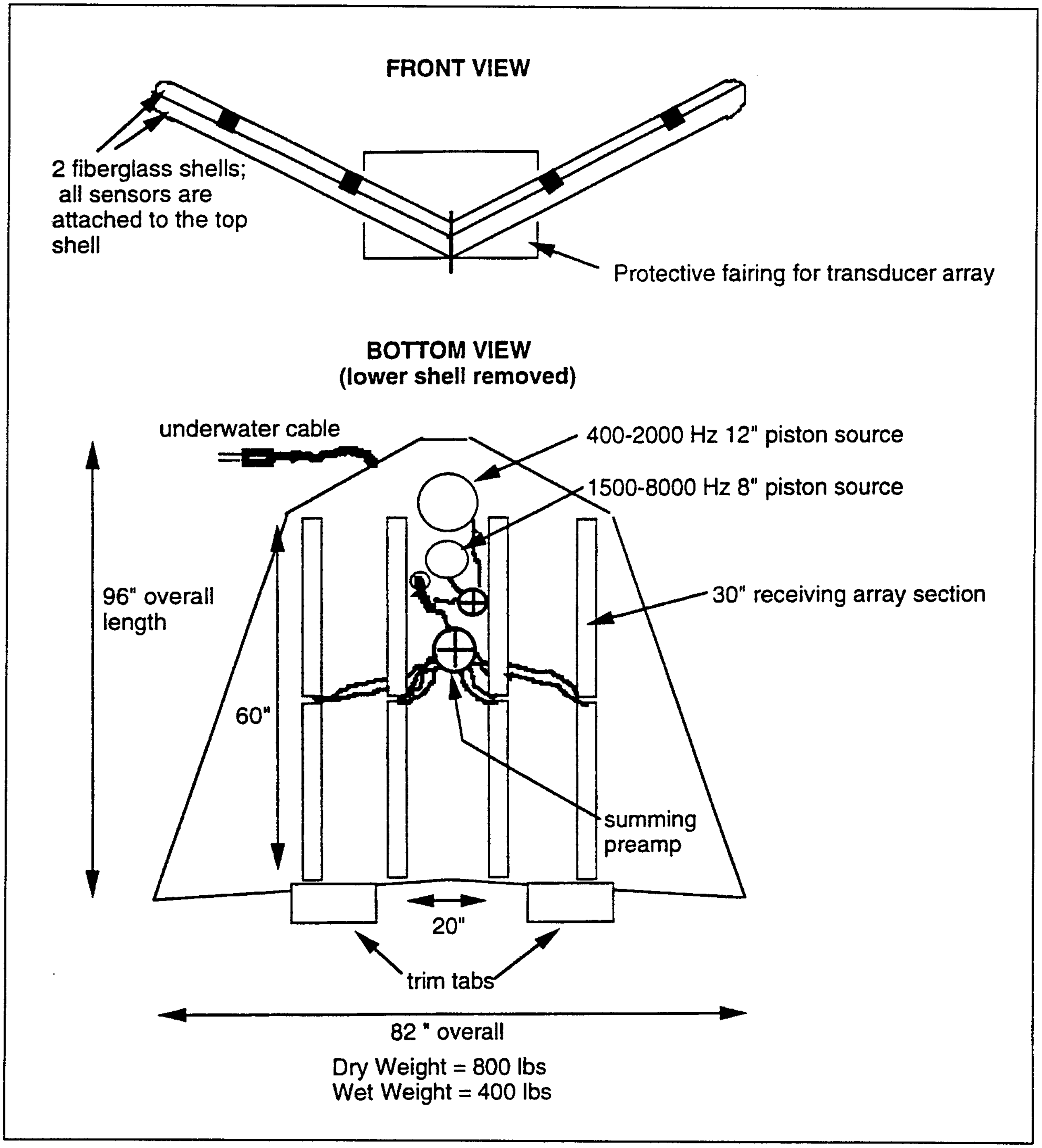


Figure 20.1 Final Design Configuration of Low-Frequency Sub-Bottom Profiler

20.2 OBJECTIVES

To design, construct, and test broadband FM sub-bottom profiling sonar for seafloor imaging and sediment classification.

20.3 PROJECT ENVIRONMENT

Offshore of Waikiki, Oahu, there are two main types of sand deposits—channel deposits (Halekulani Channel) and marine terrace deposits (Launiu Channel). Thus, these channels were chosen as the field test site because they are large, well-defined, convenient sand deposits, and a lot of work has been done on them. These channels were probably part of the ancient Manoa stream drainage and were cut during ancient low sea stands. In approximately 240 ft of water, there is a marine terrace. The theory is that the terrace is overlain by significant deposits of sand, which may be composed partially of ancient beach deposits and material transported offshore.

20.4 METHODOLOGY AND RESULTS

The FY93 provided several important findings for optimizing the profiler in FY94. The acoustic imaging of thick sand deposits, buried coral, and volcanic structures was possible using broadband chirp pulses if the pulses had energy below 1000 Hz. Conventional chirp sonars operate over 2 kHz. The tests confirmed that the sediments offshore of Oahu have much higher adsorptions and higher volume scattering than sediments in most other ocean environments that have been studied during ONR and NRL investigations. A pulse band of 400 to 2400 Hz was very effective for imaging most subbottom structures in Hawaii. This low frequency band required long arrays (at least 1.5 meters in length) to keep the directivity high in order to limit scattering noise. The 400 to 2400 Hz band did not provide adequate vertical resolution for imaging the sediment structures in some areas. Attempts to operate the sonar in the range of 2400 to 3000 Hz caused some ringing in the acoustic pulse that caused the image to be blurred near the sediment-water interface. This ringing was caused by overdriving the transducers in the crossover frequency range. Improved transmitter performance was required in mid-band. Operating two transducers with overlapping frequency bands required a crossover network to flatten the spectrum and to provide a better impedance match to the transmitter over the operating band. Operating above 10 kHz was not necessary because of high scattering and attenuation at those frequencies. This requirement allowed the transducer covering the range of 2 to 12 kHz to be redesigned to generate acoustic energy over the band of 1.5 to 10 kHz providing a 12 dB improvement in source level in the crossover region.

The FY94 work focused on the following tasks. (1) Final design and assembly of an optimized subbottom vehicle for imaging and classifying Hawaiian sands using the results of the prototype vehicle tested in FY93. (2) Code sediment classification algorithms so the FM sonar will generate real time profiles of sediment properties. (3) Establish sediment classification field test site and conduct field study to test the accuracy of sediment property predictions using the FM profiler.

The vehicle was optimized with several physical changes like a new baffle design, the addition of fins and trim tabs, and a new frame design. These

changes improved the handling of the profiler during set-up and deployment, and made the profiler more stable in the water. The turn ratio of the transformers, the series tuning inductor, and the series resistance were adjusted to provide the best performance over the frequency range of 0.4 to 10 kHz.

The sediment classification algorithms are based on quantitatively measuring the acoustic properties of the normal incidence reflection data from the subbottom profiler. Adding sediment classification capability to the profiler software required three major software development tasks. The first entailed coding algorithms for measuring the reflection coefficient and impedance, attenuation, and volume scattering from the subbottom acoustic data. The second task was developing a Graphical User Interface that displayed these acoustic parameters, and allowed the user to perform a variety of acoustic analyses and measurements in subbottom areas of interest. The third task required developing an expert system and interactive interface. The expert system is a database of lookup tables that relate the acoustic parameters to sediment properties. The interactive interface permits the user to add additional data to the expert system.

Sediments and sedimentary environments in Hawaii and the Pacific can be significantly different from those in the continental U.S. that are often used for the empirical relationships relating acoustic parameters and sediment physical properties. Therefore, it was important to verify the subbottom sediment classification results in Hawaii with actual measurements in Hawaii.

Test sites were established in several areas offshore of Oahu with different sediment types and sands with varying grain sizes. At each test site, the contractor did a subbottom survey to identify areas with different acoustic properties, and then collected sediment samples in these areas. The test sites included the Halaekulani sand channel off Waikiki, the Honolulu Harbor off Pier 37/38, the Maili and Pokai sand deposits on the Waianae coast, and offshore from the Airport Reef Runway near the Pearl Harbor entrance channel.

A total of twenty-one sediment samples were collected form the four test site areas. Each sediment sample was analyzed to determine the grain size and grain size distribution, and the degree of grain size sorting. Bulk density was also measured because it is an important parameter relating to acoustic properties measured by the profiler. Using the profiler, the sediment classification software was used to measure the reflection coefficient and impedance at each sample site. Then the physical grain characteristics were compared to the geophysical data. This is the first time such a data set was generated for Hawaiian sediments. The data demonstrated that the Hawaiian sediment acoustic-physical property relationships vary significantly from the average worldwide relationships.

The profiler is capable of penetrating 50-100 meters in sand, 200-500 meters in silt, and >500 meters in clay or mud. The vertical resolution is 20-100 cm depending on the pulse band selected. Sea Engineering has used the system in Hawaiian waters for sand mapping, sea level history investigations, and assessment of outfall pipeline route stability. As shown in Figure 20.2,

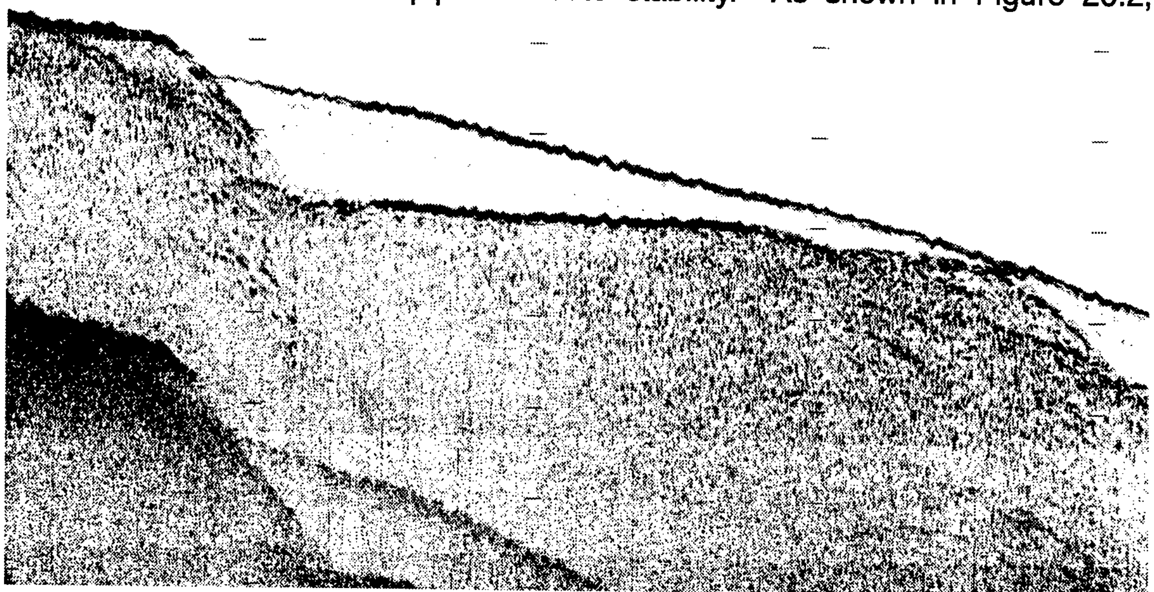


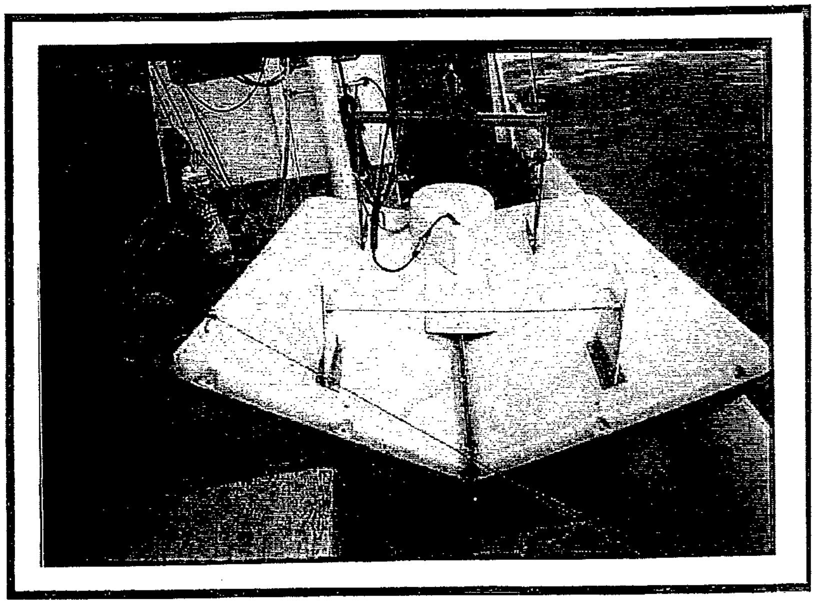
Figure 20.2 Sub-Bottom Image off Oahu showing old terrace filled with sand

this sub-bottom profiler produced the clearest images of Hawaii's sub-bottom structure to date, and revealed important, new information on offshore sedimentary structures. The Geological Survey of the United States Department of the Interior contracted with Sea Engineering, to conduct an acoustic survey of sediment deposits in Kailua Bay, O'ahu using the profiler developed under this project. The survey's chief acknowledged the Sea Engineering system as providing excellent records to support deposit volume, composition, and history estimates.

20.5 PRODUCTS

20.5.1 Commercial Products

Sea Engineering markets unique services with the sonar fish, shown in Figure 20.3.



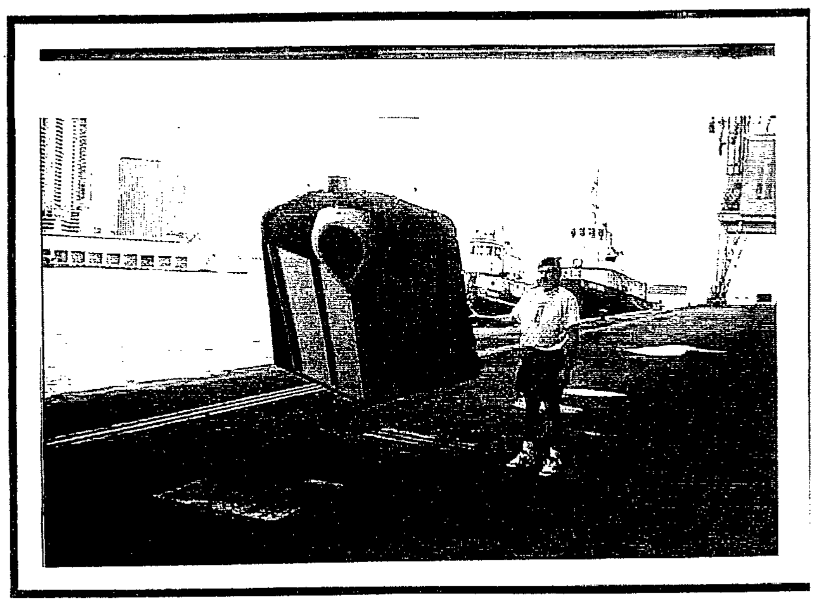


Figure 20.3 Top View and Underside view of Sonar

Sea Engineering has used the system in Hawaiian waters for sand mapping, sea level history investigations, and assessment of outfall pipeline route stability. This sub-bottom profiler produced the clearest images of Hawaii's sub-bottom

structure to date, and revealed important, new information on offshore sedimentary structures. Subcontractor Precision Signal used experience from this project to develop a commercial sonar fish that it markets (through EdgeTech) to the oceanographic research community.

20.5.2 Papers, Patents, and Disclosures

No patents or invention disclosures were filed based on this work. The following papers were published about this project.

A New Broad Band Frequency Modulated Subbottom Profiler Developed for Hawaii. James Barry, Steven G. Schock, and Marc Ericksen. Proceedings of the Seventh (1997) International Offshore and Polar Engineering Conference (ISOPE 97), Honolulu, USA, May 25-30, 1997, pp. 120-127. NOTE: CEROS needs copy of this paper.

Sub-Bottom Imaging of the Hawaiian Shelf. Marc Ericksen, James Barry, and Dr. Steven G. Schock, Sea Technology, June 1997, pp. 89-92.

Development of a Broad-Band Frequency Modulated Subbottom Profiler. Marc Ericksen and James Barry. Pacific Congress on Marine Science and Technology, 1996 (PACON '96), Honolulu, Hawaii, June 17-22, 1996, p. 9.

Tracing Discharges in Ocean Environments Using a Rare Earth Tracer. Susan C. Paulsen, E. John List, Robert Y. Rocheleau, and Theodore S. Durland. Water for a Changing Global Community XXVII IAHR Congress, San Francisco, 10-15 August 1997.

Fishing the Deep. Greg Ambrose, Honolulu Star-Bulletin, March 12, 1996.

20.6 IMPACT

20.6.1 Job Creation

This contract supported $43,000 in labor at Sea Engineering (Hawaii) where a project engineer, ocean engineer, and a marine technician worked 16, 42, and 13 days, respectively. This contract supported $101,500 in labor at Precision Signal (Florida) where a project engineer, programmer, and assistant worked 55, 130, and 35 days respectively.

The contractor estimates that one full time job in Hawaii was created by CEROS contracts. This position has been sustained primarily by the capabilities developed during the work on the sub-bottom profiler. Sea Engineering completed two prestigious contracts with the U.S.G.S. using the CEROS sub-bottom profiler to map sand deposits around Oahu. The sub-bottom data produced by the profiler is excellent, and the USGS was very happy with the results. The contractor also received several contracts to conduct geophysical surveys for fiber optic cable systems around the world. They conducted these surveys in Hawaii, Fiji, California, Florida, New York, Puerto Rico and Martinique.

20.6.2 Business Development

Sea Engineering took the following steps to develop business contracts based on the Sub-Bottom Profiler developed with CEROS funding:

- Wrote an article about the project for Sea Technology
- Conducted an at-sea demonstration of the system for local industry and professionals.
- Presented the project results to the Navy's science advisor and his staff.
- Developed a special company brochure insert.
- Worked with a local news reporter to have a newspaper article published on the project. This article was published on the front page of the Star Bulletin.

20.6.3 Residual Benefits to Hawaii

The residual benefits to Hawaii are the development of unique capabilities and experience in geophysical surveying. As a result, Sea Engineering has been able to export this service nationwide and internationally.

20.6.4 Principal Investigator/Company Opinion

Sea Engineering believes CEROS is a valuable resource for Hawaii. Most importantly, it has provided a merit-based, competitive means of funding research projects to address Hawaii's special needs. CEROS is doing an excellent job, and the contractor has no suggestions for improvements at this time.

20.6.5 Impact on Principal Investigator/Company

This CEROS contract had a beneficial impact on the PIs and the company by providing unique capabilities and experience, including the development of relationships with individuals and organizations that they would not ordinarily have dealt with. This has widened our horizons, leading to increased opportunities for the company, including the ability to export their services overseas.

20.7 TRANSITION

In FY97 and 98, CEROS sponsored Sea Engineering and Precision Signal for a related projected. Sea Engineering has used the subbottom profiler in Hawaiian waters for sand mapping, sea level history investigations, and assessment of outfall pipeline route stability, including a contract with the Geological Survey of the United States.

21.0 Hyperspectral Remote Sensing (AAHIS) for Maritime Applications: Phase II

ABSTRACT

In this project, SETS Technology, now known as Science & Technology International (STI), developed the first hyperspectral sensor system with the required signal-to-noise ratio (SNR) and spatial and spectral resolution adequate for advanced maritime applications. During the first phase of the project, a flight-tested, visible/near-infrared (430 to 840 nm) hyperspectral imaging system, was optimized for use in maritime applications—advanced airborne hyperspectral imaging system (AAHIS). The AAHIS system offers the ability to do high-speed, wide-area surveillance from an airborne platform.

Under CEROS FY93, STI adapted its proprietary signal-processing scheme into a prototype airborne hyperspectral imaging system for near-shore surveillance and mapping, adapted advanced sensor system into marine applications. The FY94 effort focused on improving the resolution of the advanced airborne hyperspectral imaging system (AAHIS), and demonstrated the system's capabilities. STI increased the search rate, resolution, and accuracy of the AAHIS system and demonstrated specific applications. STI increased spatial resolution five-fold, incorporated image stabilization into the AAHIS flyaway package, provided on-board real-time spectral image processing, and integrated differential GPS with a geographic information system.

The AAHIS flight navigation system was completed, and high resolution AAHIS data were collected from Kaneohe Bay. A mirror stabilization system for AAHIS was developed by SETS to meet project schedules and deadlines. SETS has "captured" a technology from SAIC and developed it within a specific maritime, littoral niche. DoD demonstration of AAHIS technology application being coordinated through the Navy Technology Insertion Program (NTIP). Based on the work sponsored by CEROS, STI has secured over $10 million in funding from other federal sources to continue development of AAHIS-related projects.

Contractor: Science & Technology International, Inc. (formerly SETS Technology)
733 Bishop Street
Makai Tower, Suite 3100
Honolulu, HI 96813
phone: 808-540-4700

Subcontractor: SAIC
Newport, RI

Principal Investigator: Thomas McCord
current contact is Ron Seiple

Contract Number:	Contract Amount:	Funding Year
38101	$647,974	FY94

Start Date:	Completion Date:
November 1994	April 1996

21.1 BACKGROUND AND TECHNICAL DESCRIPTION

21.1.1 Background

Over the past decade the Department of Defense (DoD) has documented a wide variety of strategic and tactical requirements in defense and intelligence that call for a passive airborne, optical spectral (color) remote-sensing capability. In addition, many civilian and environmental applications require the same remote-sensing capability, including bathymetry, reef inventories, water-quality monitoring, biota monitoring, ocean-productivity monitoring, and current mapping. Obtaining this information in a timely way from imagery gathered remotely is the ultimate goal of remote sensing.

Multi- and hyperspectral imaging spectrometry is the technique of obtaining photometric images of a scene at different spectral bandpasses (colors). Multispectral imaging uses only a few (3-10) broad and noncontiguous spectral channels, as in the well-known spaceborne Landsat Thematic Mapper sensor. Hyperspectral imaging is more powerful because many (10's to 100's) narrow and contiguous spectral channels are sensed. Because the materials that comprise the objects in a scene reflect light differently at different regions of the spectrum, each image shows a different set of contrasts among the materials in the scene. This set of images contains far more information about the scene than a red-green-blue color image from conventional video.

Hyperspectral imaging (imaging all colors simultaneously) is much more effective than panchromatic imaging (imaging at one broadband spectral channel). All materials reflect radiation across the electromagnetic spectrum in ways often unique for each material; i.e., most materials have a unique spectral signature. The natural spectral widths of features in these signatures require hyperspectral resolution for optimum detection, discrimination, and identification of materials. Image products that exploit the spectral data contained in AAHIS hyperspectral images provide information about the types, compositions, and locations of substances visible in an image.

21.1.2 Technical Description

AAHIS is an operational, high signal-to-noise ratio, high resolution, integrated hyperspectral imaging spectrometer. The compact, light-weight and portable AAHIS system is normally flown in a Piper Aztec airplane. AAHIS collects "push broom" data with 385 spatial channels and 288 simultaneous spectral channels from 433 nm to 832 nm, recording at 12 bits up to 55 frames/second. Typical operation incorporates on-chip pixel binning of four pixels spectrally and two pixels spatially, increasing the signal-to-noise ratio and reducing data rate. When binned, the spectral resolution is 5.5 nm and the instantaneous field-of-view (IFOV) is 1 mrad. The sensor is optimized for littoral region remote sensing for a variety of civilian and defense applications including MCM, ASW, reconnaissance, ecosystem surveying and inventory, detection and monitoring of environmental pollution, infrastructure mapping, and surveillance. Figure 21.1 shows a block diagram of AAHIS. Figure 21.2 shows the AAHIS camera/spectrometer assembly.

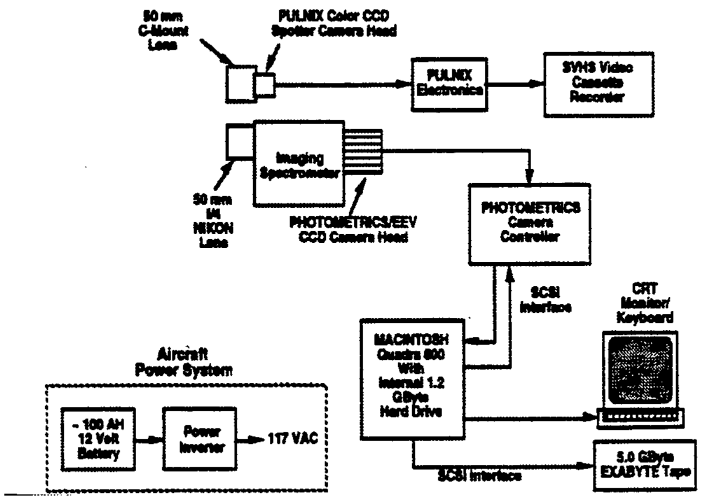


Figure 21.1 AAHIS s[illegible]ock diagram

21.2 OBJECTIVES

This project sought to detect, identify, and map near-shore features of interest to Navy/Marine Forces, ocean environmental preservation concerns, and Hawaii, using an innovative, passive airborne, hyperspectral imaging system never before applied to underwater features. These features include underwater obstructions, reefs, beaches, pollutants, effluents, bottom topography, mines, unexploded ordnance, near-beach soil, and flora and fauna. During this second phase of the project, the contractor sought to enhance the optical sampling, reduce data processing time, provide in-flight mission optimization, and add a GIS reference from an airborne differential Global Positioning System to the data.

21.3 PROJECT ENVIRONMENT

From its inception until April 1997, SETS Technologies had offices with computer and electronics labs located in Mililani on Oahu. Since April 1997, the company has been known as Science & Technology International (STI) and is located in downtown Honolulu.

The data were processed using STI's proprietary hyperspectral image processing software (HIPS™). HIPS is a commercially available Sun/UNIX workstation-based package and is a full-featured spectral image-processing system with unique capabilities for processing hyperspectral image data sets. At the termination of a data-gathering flight, a tape cartridge containing raw imagery is produced, ready for analyzing, displaying, and printing. In addition, an SVHS videotape containing the spotter camera's record of the ground track is produced, allowing the data analyst to correlate the naked-eye view of the scene with the hyperspectral imagery.

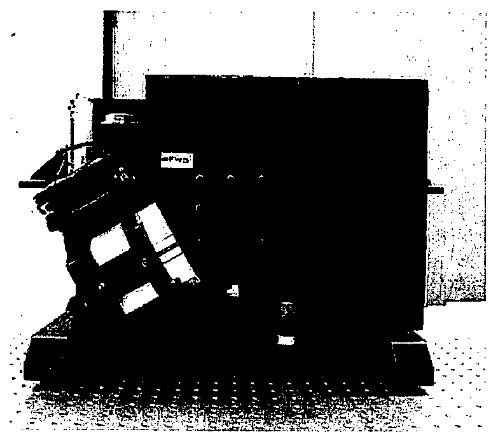


Figure 21.2 AAHIS camera/spectrometer assembly

21.4 METHODOLOGY AND RESULTS

Sensor Field Calibration. The AAHIS absolute calibration was performed using the Labsphere integrated calibration system. The system was then compared against ground truth data available from the Desert Radiance data collection using the HYMSMO and LOWTRAN and MODTRAN models for atmospheric characterization. Good agreement was found except in the blue wavelengths. To resolve the discrepancy, absolute calibration of the AAHIS sensor was performed using a blue filter in front of the AAHIS foreoptics. Calibration with this filtered source yields good agreement with LOWTRAN predicted spectral irradiance curves for the HYMSMO data. Calibration is routine and provides the customer with the NIST traceable correction values to convert the digital numbers to spectral radiance values.

Image Stabilization. Without image stabilization, small angular motions of the aircraft introduce large shifts on the ground of the area being imaged. This appears as a waviness in the images so that linear features like roads and runways appear curved or sinuous. A Zeiss image stabilization system and a mirror-based 3-axis gimbal system from SpecTIR were investigated but neither system met the requirements. The contractor turned to computer modeling to create an image stabilization subsystem. One of the unique accomplishments of this project was the implementation and testing of an active stabilization algorithm for the AAHIS sensor. The active approach developed by the contractor was a substantial advance in the state of the art over passive mechanical approaches used by other companies. In addition, the integration of the Flight Navigation System with differential GPS navigation provided a positive, non-imaging means to determine "down." Active stabilization requires real-time, computer-controlled adjustment of the optical path in response to linear and rotational motion of the platform while data is being collected. The contractor used the C++ language to program the compiler to solve a non-linear set of twenty equations in three unknowns using the generalized inverse method based on singular value decomposition theory.

Another unique aspect of the stabilization approach developed here is the seamless integration with navigation and the tactical aspects of image data acquisition. While in regional mapping mode, one of several collection modes provided, the navigational software controls all aspects of the data collection process. Based on an imaging pattern entered into the navigational computer before a mission, the flight navigation system provides a dynamic map display showing the progress of the mission, activates acquisition of the data automatically as the aircraft flies over the targeting area, adjusts the optical path to compensate for aircraft position and orientation, and provides real-time flight correction data to the pilot using an avionics display in the cockpit. The result is a system that is easy to use, requires very little decision making during flight operations, and greatly enhances the probability of successful data collection.

Differential GPS Flight Navigation System. This system was subcontracted to SAIC of Newport, Rhode Island, led by Roger Ward. A new dGPS receiver operating in the UHF band was integrated into the Flight Navigation System so that dGPS position data may be received in both the 385 KHz (Coast Guard frequency) and the 409 MHz band (most portable dGPS stations). A pilot navigation aid in the form of an analog cross-track-error indicating needle was built and debugged. Coupled with this was the demonstrated ability of the dGPS receiver to receive signals and relay them to the Ashtech GPS receiver. This new subsystem is part of the Flight Navigation System (FNS). Procedures were developed to transfer FNS position data from the FNS computer to the laboratory AAHIS data processing system (ARCVIEW GIS) to provide position data for each image cube data set. Flight plans (surveys) are easily loaded into the FNS computer.

Real-Time Processing. Real-time processing of recorded AAHIS data (at full frame rate) has been demonstrated. The contractor used a unique and innovative real-time, on-board, spectral image acquisition and processing system based on the SCANNER™ image processing software (WTJ Software Services).

Helicopter Integration. This phase of AAHIS development had included a helicopter deployment to reduce speed so that spatial resolution could be increased. However, data collected from small fixed-wing airplanes resulted in high resolution ground sample distances and was preferred by the contractor's customers over a helicopter deployment. CEROS concurred that the helicopter adaptation could be abandoned. In the long term, the hyperspectral imaging camera frame rate will be increased to increase the along-track spatial resolution.

High Resolution Data Flights. The AAHIS system produced high resolution data products over a variety of locations in Hawaii and outside the state. These data have been for military and environmental/commercial applications. Figure 21.3 shows data collected during the Island Radiance program using the AAHIS system.

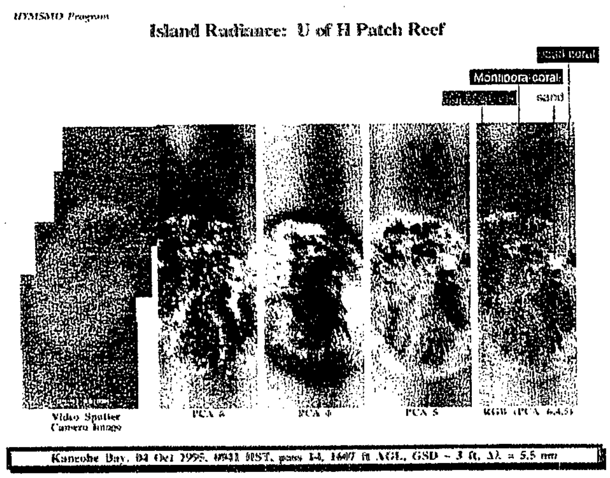


Figure 21.3 AAHIS data collected over a patch reef for Island Radiance project

21.5 PRODUCTS

<u>21.5.1 Commercial Products</u>

The Advanced Airborne Hyperspectral Imaging System (AAHIS) is a remote sensing tool that is flown on an aircraft. Ocean applications include mapping bathymetry, taking reef inventories, monitoring water-quality, monitoring biota and ocean productivity, and mapping oceanographic currents.

21.5.2 Papers, Patents, and Disclosures

No invention disclosures or patents were filed based on this project. STI holds the hardware and software as proprietary knowledge and has acted to protect it as necessary. Several papers and presentations were published about this work.

Wide Field-of-View Stabilized Hyperspectral Sensor Systems. James Karins, Robert Lintell, Darcy Hart, Brad Speer, Rick Holasek, Fred Portigal, and Greg Mooradian. International Symposium on Spectral Sensing Research (ISSSR), San Diego, California, December 13-19, 1997.

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Coral and Vegetation Mapping using the Advanced Airborne Hyperspectral Imaging System (AAHIS). Holasek, R.E., Portigal, F.P., Even, D.M., Johnson, P., Segawa, M., and Susner, G.. *IGARSS 98'*, Seattle, Washington, 6-10 July, 1998.

Vegetation Mapping using the Advanced Airborne Hyperspectral Imaging System (AAHIS). Holasek, R.E., Portigal F.P., and Karins, J.P.. *1st International Conference on Geospatial Information in Agriculture and Forestry*, Lake Buena Vista, Florida, 1-3 June, 1998.

Environmental Mapping using the Advanced Airborne Hyperspectral Imaging System (AAHIS). Holasek, R.E., Portigal, F.P., Even, D.M., Johnson, P., Segawa, M., and Susner, G.. *GISMAP 98'*, Kahala, Hawaii, 7-8 April, 1998.

Fanbeam Hyperspectral Acquisition for Underwater Applications. Yafuso, E. Seiple, R. and Anderson, R. MTS/IEEE Oceans 99. Seattle, WA, September 13-16, 1999.

The Mapping of Littoral and Coastal Zones Using a Hyperspectral Imaging System. M. Grant Susner, David Breitwieser, Miguel Busquets, Rick LaMont, Sid Pang, Mark Segawa. Oceanology International '99 Pacific Rim, Singapore, April 27-29, 1999.

21.6 IMPACT

21.6.1 Job Creation

This contract supported portions of fourteen positions at STI including managers, scientists, engineers, technicians, programmers, and administrators for a total of 3,836 labor hours and a total of $115,987 labor dollars. The bulk of the work was conducted by the technical staff.

When STI received its first CEROS contract in 1993, it employed around 17 full-time workers. As of the time of this report, STI employs 55 employees including 5 on the Big Island and 6 on Maui. STI projects growing to 100 employees within the next year, and the company is willing to establish satellite offices on the neighbor islands to accommodate skilled engineers who prefer to live outside Oahu. Also, STI seeks to hire Hawaii people who have been trained or work on the mainland and desire to return to a high-tech position in Hawaii.

21.6.2 Business Development

STI has received several government and DoD contracts to develop and implement its hyperspectral imaging devices. STI recently received nearly $12 million from the DoD for military applications and another $4 to 5 million from another government agency for medical imaging applications.

21.6.3 Residual Benefits to Hawaii

This product will be manufactured and marketed from Hawaii by a Hawaii corporation providing long-term income to the state. Applications in the medical field are likely.

21.6.4 Principal Investigator/Company Opinion

Working with CEROS is fabulous. The CEROS staff is professional and cooperative. The fixed price contract vehicle is good for the company, and it aids the company to be able to suggest the payment schedule based on project milestones. The ability to keep title to the technology is very valuable to the company.

21.6.5 Impact on Principal Investigator/Company

The CEROS contracts have formed the basis of all hyperspectral devices being developed and implemented by STI. STI has built a significant business in Hawaii and the CEROS-funded projects will generate nearly 90% of its business in FY99 with gross revenues on the order of millions of dollars per year.

21.7 TRANSITION

STI transitioned the AAHIS technology to the Thermal AAHIS, the Littoral Airborne Sensor Hyperspectral (LASH), and to a medical imaging device, the HyperSpectral Diagnostic Imager. Related technologies at STI are the Dual Mode Fluorescence Imager (DFI) and the Grazing Angle Imaging Lidar (GAIL).

22.0 Grazing Angle Imaging Lidar (GAIL) for Organic Mine Countermeasure

ABSTRACT

SETS Technology, Inc., now known as Science & Technology International (STI) developed and demonstrated a prototype "grazing angle" (4 to 6 degrees below horizontal) imaging LIDAR system for detecting and discriminating objects in shallow water. This prototype mine countermeasure system is based on the LIDAR return of pulsed LASER light at near incident grazing angles to the sea surface.

As part of the CEROS-sponsored effort, STI performed a mission analysis and concept definition study for grazing angle LIDAR systems. STI contends that a system such as GAIL could function as an "organic" (that is, own ship) mine countermeasure system for escort ships in a battle group, on landing craft, or as part of a point defense system ashore or afloat.

In addition to the system concept definition study STI assembled a "breadboard" system, tested the system at NELHA, and developed a top-level system description for an operational GAIL MCM system. The resulting system model identifies the landing craft mounted system as the leading candidate for a "real world" GAIL application.

During tests at NELHA, the breadboard GAIL system demonstrated single pulse detection of mine-like targets in clear ocean water to depths of 65 feet. STI reports that greater detection depths would be possible with more elaborate real-time signal processing for the signals. For the tests, the prototype system used a frequency-doubled flashlamp pumped Nd:YAG laser from Big Sky Laser with maximum output energy at 532 nm wavelength of 125 microjoules per pulse. The laser operated at a pulse repetition frequency between 10 and 30 Hz. STI developed and installed a unique "haul down" mooring system to test the GAIL prototype at NELHA. STI conducted the proof-of-concept testing at NELHA efficiently and in full compliance with FAA, Coast Guard, and environmental regulations.

The STI effort showed that the GAIL system concept is practical and that the preliminary system model is valid. Results are sufficient to support development of a prototype sensor system. However, STI also recommends further testing to refine the system concept for operational utility.

Contractor: Science & Technology International, Inc. (formerly SETS Technology)
733 Bishop Street
Makai Tower, Suite 3100
Honolulu, HI 96813
phone: 808-540-4700

Subcontractor: SAIC
San Diego, CA

Principal Investigator: Greg Mooradian
current contact is Ron Seiple

Contract Number:	Contract Amount:	Funding Year
41357	$698,277	FY96

Start Date:	Completion Date:
September 1996	December 1997

22.1 BACKGROUND AND TECHNICAL DESCRIPTION

22.1.1 Background

Vice Admiral Katz has said that "the biggest threat to the Persian Gulf is mines. They are the fastest way to clog up the Strait of Hormuz, which would have a major impact on the world oil supplies." During the Gulf War of 1991, damage to U.S. surface forces was due largely to unsophisticated sea mines. To be effective, the mine countermeasure (MCM) capability must be onboard the protected ship, and provide real-time alerts and mapping.

This program demonstrated the feasibility of the first Grazing Angle Imaging LIDAR (GAIL) to mine countermeasures. A blue-green laser is capable of penetrating the sea surface environment (where acoustic and radar systems are inadequate) to detect submerged and surface mines. In actual deployment, a mast-mounted GAIL would look ahead of a transiting vessel to warn of mine threats in time for evasive or neutralization action. To employ LIDAR for MCM operations from a surface ship requires the laser beam to enter the water at near grazing angles to the surface of $\leq$ 6 degrees to obtain operationally useful ranges.

22.1.2 Technical Description

The breadboard GAIL system was comprised of a frequency-doubled, Q-switched Nd:YAG laser emitting green light at 532nm, output beam shaping optics, a pan and tilt output and signal collection mirror, a receiver telescope, a photomultiplier detector, a high bandwidth signal digitizer, and timing, control and data acquisition electronics and software. The combination high bandwidth detection/cueing and imaging confirmation/classification LIDAR features a 500 foot range (mast height dependent), greater than 60 foot depth capability, and up to 180° forward area coverage scan. The control and data system features a GPS and INS-based stabilization system, automated dual-mode target confirmation and classification upon detection, automated target mapping and data storage, automated tracking/target designation, and data link compatibility with combat display and weapons systems.

22.2 OBJECTIVES

Science & Technology International (STI) sought to develop and demonstrate a prototype "grazing angle" (4 to 6 degrees below horizontal) imaging LIDAR system for detecting and discriminating objects in shallow water. STI contends that a system such as GAIL could function as an "organic" (that is, own ship) mine countermeasure system for escort ships in a battle group, on landing craft, or as part of a point defense system ashore or afloat.

22.3 PROJECT ENVIRONMENT

From its inception until April 1997, SETS Technologies had offices with computer and electronics labs located in Mililani on Oahu. Since April 1997, the company has been known as Science & Technology International (STI) and is located in downtown Honolulu. The GAIL fieldwork was conducted along the coastline at the Natural Energy Laboratory of Hawaii (NELH) at Keahole Point outside Kailua-Kona on the Island of Hawaii.

22.4 METHODOLOGY AND RESULTS

STI developed a comprehensive interactive GAIL performance model, performed a concept definition study, developed field plans and procedures, designed and assembled a breadboard system, and conducted field experiments at NELH on the island of Hawaii. Figure 22.1 shows a photograph of GAIL under operation at night. After the fieldwork, STI reduced and interpreted the data, and developed a full system description for GAIL MCM. The work plan included laser eye safety, and permits from the U.S. Coast Guard.

Successful proof-of-concept demonstrations on the Kona, Hawaii coast detected mine-like objects to a depth of 65 feet while validating a detailed ocean and atmospheric optics performance model. The operational GAIL system includes a laser illuminator and optical receiver that determine depth and location information on mines within a scanned coverage area around the ship. Mine locations are tracked on each successive scan, enabling the ship to maneuver safely. Though designed for military MCM, the GAIL concept has potential commercial applications where there is a need for rapid detection of underwater obstructions such as in harbor maintenance or commercial fishery operations.

Figure 22.1 Operation of GAIL at night at NELH

Some of the benefits of GAIL are:

- Immediately deployable by the asset that needs it most, the surface ship proceeding into mined waters,
- Detects mines in the clutter-rich sea surface and shallow-water depth zone that foils sonar and radar,
- Penetrates the seawater blue-green transmission window and far forward of the advancing vessel to detect and track mines in real time, and
- Status display enables the ship to maneuver to avoid the threat, or to effect prosecution with shipborne weapons.

22.5 PRODUCTS

22.5.1 Commercial Products

A "breadboard" prototype was demonstrated under this contract and no commercial products were produced directly from this project.

22.5.2 Papers, Patents, and Disclosures

No invention disclosures or patents were filed based on this contract. One paper was presented about this work.

Grazing Angle Imaging LIDAR (GAIL) for Organic Ship MCM. James G. Leatham, Bradford A. Speer, Cye H. Waldman, Kirk E. Davies, and Barry A. Swartz. Symposium on Technology and the Mine Problem, Monterey, California, April 6-9, 1998.

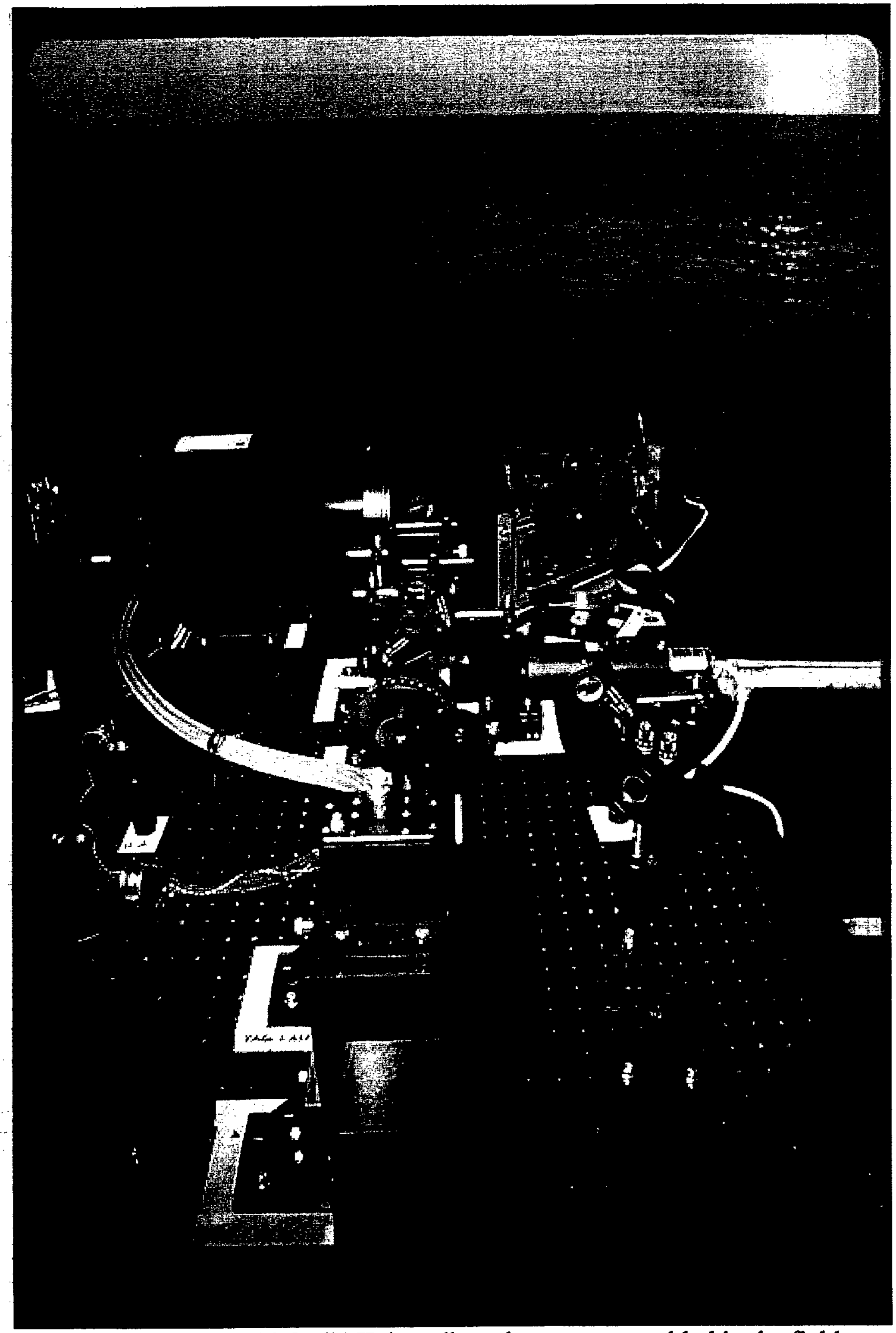


Figure 22.2 GAIL breadboard system assembled in the field

22.6 IMPACT

22.6.1 Job Creation

This contract supported portions of eleven positions at STI including managers, scientists, engineers, technicians, programmers, and administrators for a total of 3,772 labor hours and a total of $137,346 labor dollars. The bulk of the work was conducted by the technical staff.

When STI received its first CEROS contract in 1993, it employed around 17 full-time workers. As of the time of this report, STI employs 55 employees including 5 on the Big Island and 6 on Maui. STI projects growing to 100 employees within the next year, and the company is willing to establish satellite offices on the neighbor islands to accommodate skilled engineers who prefer to live outside Oahu. Also, STI seeks to hire Hawaii people who have been trained or work on the mainland and desire to return to a high-tech position in Hawaii.

22.6.2 Business Development

STI has received several government and DoD contracts to develop and implement its hyperspectral imaging devices. STI recently received nearly $12 million from the DoD for military applications and another $4 to 5 million from another government agency for medical imaging applications.

22.6.3 Residual Benefits to Hawaii

This project allowed STI to demonstrate a leading edge technology. STI gained considerable engineering experience that it has applied in other lucrative projects.

22.6.4 Principal Investigator/Company Opinion

Working with CEROS is fabulous. The CEROS staff is professional and cooperative. The fixed price contract vehicle is good for the company, and it aids the company to be able to suggest the payment schedule based on project milestones. The ability to keep title to the technology is very valuable to the company.

22.6.5 Impact on Principal Investigator/Company

The CEROS contracts have formed the basis of all hyperspectral devices being developed and implemented by STI. STI has built a significant business in Hawaii and the CEROS-funded projects will generate nearly 90% of its business in FY99 with gross revenues on the order of millions of dollars per year.

22.7 TRANSITION

STI would like to continue developing this technology.

23.0 Dual Mode Fluorescence Imaging for Maritime Applications

ABSTRACT

SETS Technology, now known as Science & Technology International (STI), proposed to develop and demonstrate a dual mode, multi-spectral fluorescence imaging system (DFI) for through-the-surface and subsurface maritime applications. The DFI system would be the first to use both ultraviolet and visible wavelengths in a dual mode (reflectance and fluorescence) imaging system. The goal of the DFT/SHI is to provide quantitative, nondestructive remote discrimination and characterization of marine and littoral zone phenomena. Targeted missions include assessing coral reef health, mapping and dectecting benthic pollutants, tracking contaminant streams, mapping plankton, mapping fish, and mine and unexploded ordinance detection/discrimination. The phase I work included: (1) design and assemble the DFI system; (2) collect through-the-surface and subsurface multispectral reflectance and fluorescence data from a variety of targets; (3) develop spectral discrimination algorithms; (4) develop spectral detection and characterization algorithms; and (5) validate the DFI model in Pearl Harbor and Kaneohe Bay. STI configured the DFI system to perform both laser-generated DFI and passive hyperspectral imaging from the same "pushbroom" configuration. A supplemental agreement extended the effort to provide for demonstration of system in coral reef assessment project, and an additional $100k was provided by CEROS to support demonstration (total project funding = $895k).

The phase II work plan included several system upgrades, and the integration and field-testing of the system on a helicopter. During the contract, the aircraft was changed from a helicopter to a Piper Navajo small airplane but the field testing of the full system was blocked by lack of FAA approval for the instrument housing. Ground-based tests of the active, fluorescence device were conducted at Barber's Point Naval Air Station. The passive, hyperspectral device was flown over Pearl Harbor on a Panavia aircraft. The active data was somewhat inconclusive, and the passive data was successful.

Contractor: Science & Technology International, Inc.
733 Bishop Street
Makai Tower, Suite 3100
Honolulu, HI 96813
phone: 808-540-4700

Subcontractor: SAIC
Woods Hole, MA

Principal Investigator: Greg Mooradian
current contact is Ron Seiple

Contract Number:	Contract Amount:	Funding Year
39496	$894,976	FY95
41365	$996,428	FY96

Start Date:	Completion Date:
September 1995	November 1998
September 1996	June 1999

23.1 BACKGROUND AND TECHNICAL DESCRIPTION

23.1.1 Background

The DoD needs methods to detect mines and ordnance in shallow waters, and for environmental monitoring of pollutants and coral reef health.

23.1.2 Technical Description

The Dual Mode Fluorescence Imaging (DFI) sensor delivers > 70mJ of 355nm or 150mJ of 532nm laser light in pulses with a sampling density of ~110/km2. The 10 inch diameter receiver collects fluorescence and reflected light and resolves it into 16 simultaneous channels of 13.6nm over a 264nm range that is selectable within the limits of 380-780nm. Each channel provides 256 time-resolved samples of ~5ns resolution with 12 bit instantaneous dynamic range. An active dGPS and INS-based image stabilizer with real-time pilot navigational aid is linked to the DFI. The DFI computer and timing electronics serve three functions. First, using data from the stab/nav computer, the DFI transmitter/receiver scan mirror is controlled to effect the spot sampling pattern while correcting for aircraft motion. Second, synchronization of firing the laser is coordinated with the scanning and the multi-anode pmt receiver is appropriate time gated. Finally, the DFI computer controls the collection and storage of laser reflectance and fluorescence data. Table 23.1 lists the system specifications, and Figure 23.1 depicts the DFI operational concept.

Spectral Coverage:	433–832 nm
Spectral Resolution:	288 spectral channels, nominally binned to 72 channels
DI: 1.39 nm Spatial Resolution:	768 spatial channels, nominally binned to 384 channels
Field of View (FOV):	40×
Coverage Rate:	94 km2/hr at 3000 ft
Swath Width:	222 m at 1000 ft altitude 666 m at 3000 ft altitude 1332 m at 6000 ft altitude
Ground Pixel:	0.29 m at 1000 ft altitude 0.87 m at 3000 ft altitude 1.73 m at 6000 ft altitude
Laser System Output Energy:	> 70 mJ at 355 nm > 150 mJ at 532 nm
Grid Pattern:	~ 20 m at 3000 ft altitude
Calibration:	Dark current and flat field correction

Table 23.1 System specifications of DFI.

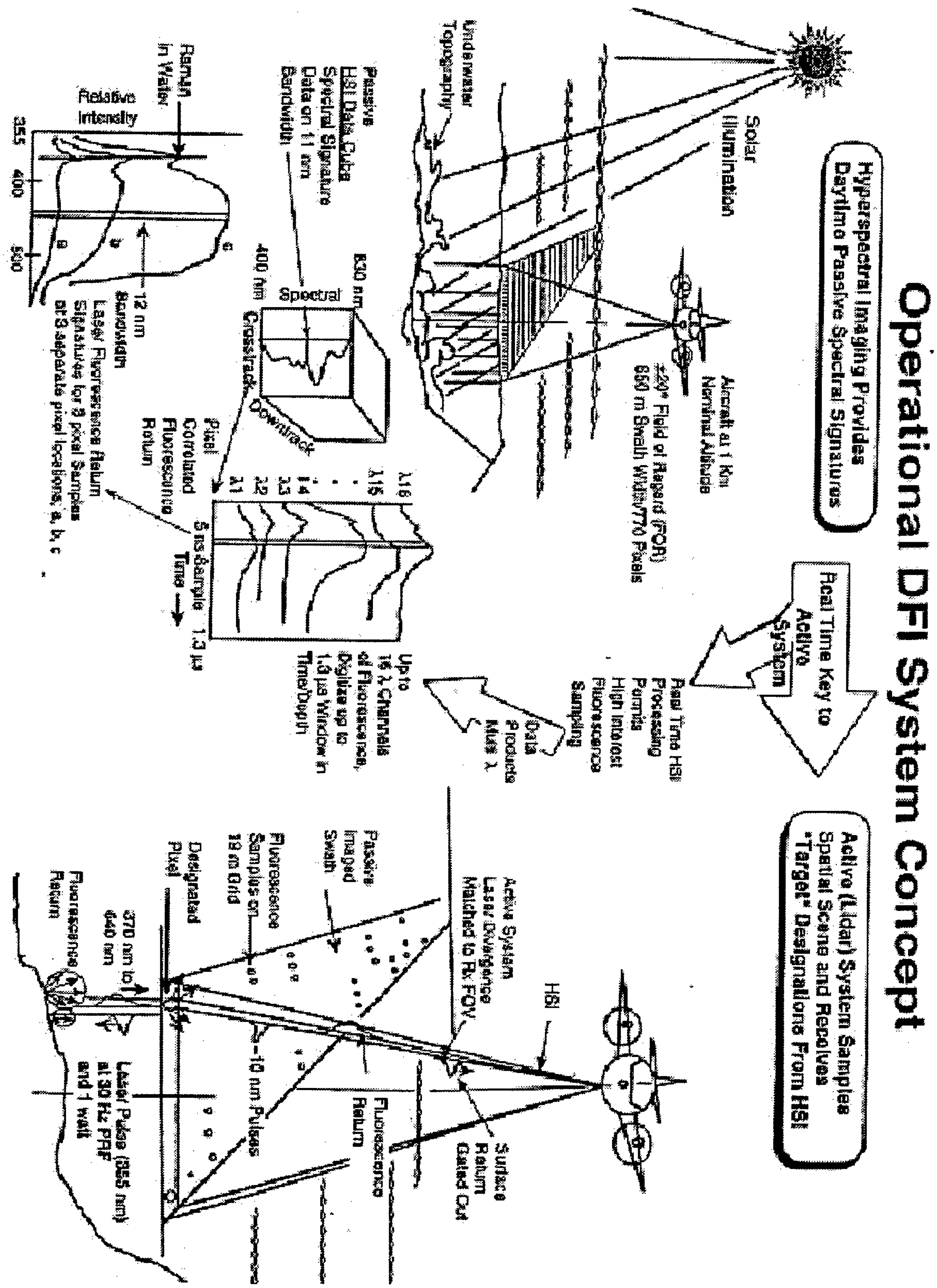


Figure 23.1 Operational DFI system concept

23.2 OBJECTIVES

SETS Technology proposed to develop and demonstrate a dual mode, multi-spectral fluorescence imaging system (DFI) for through-the-surface and subsurface maritime applications. The DFI system would be the first to use both ultraviolet and visible wavelengths in a dual mode (reflectance and fluorescence) imaging system. In phase II, SETS sought to improve the system and gain FAA approval for helicopter deployment.

23.3 PROJECT ENVIRONMENT

23.4 METHODOLOGY AND RESULTS

The phase I (FY95) work plan included: (1) design and assemble the DFI system, (2) collect through-the-surface and subsurface multispectral reflectance and fluorescence data from a variety of targets, (3) develop spectral discrimination algorithms, (4) develop spectral detection and characterization algorithms, and (5) validate the DFI model in Pearl Harbor and Kaneohe Bay. During phase II (FY96), the work plan included several upgrades to both the active (fluorescence) and passive (hyperspectral) portions of the DFI system. The main tasks were: (1) develop an integrated DFI/HSI performance model, (2) perform an operational system concept definition study, (3) develop a helicopter integration plan, (4) design and assemble operational DFI/HSI system, (5) incorporate flight dGPS NAV and stabilization system, (6) incorporate real-time processing system, (develop ground-truthing plan and hardware, (7) conduct lab testing and helicopter integration, test the system in diverse environments, and (8) perform data reduction and interpretation.

The contractor successfully completed most of the tasks as originally planned. However, during phase II CEROS agreed that the contractor could change the helicopter integration plan to a Piper Navaho fixed-wing, dual-propeller airplane. Then, the "canoe" housing the instrument on the belly of the Piper Navaho did not receive FAA certification and the instrument was not operated from the air. The active laser portion was then ground-tested at Barber's Point Naval Air Station on June 25, 1999 during a clear, full-moon night. The DFI scanner was operated in line mode and fired parallel to the ground at a target array. Figure 23.2 shows the STI engineers in the field with the DFI scanner at Barber's Point. The passive hyperspectral portion was installed on a Panavia aircraft and flown over Pearl Harbor. Sample data from the mission flown on August 12, 1998 is shown in Figure 23.3.

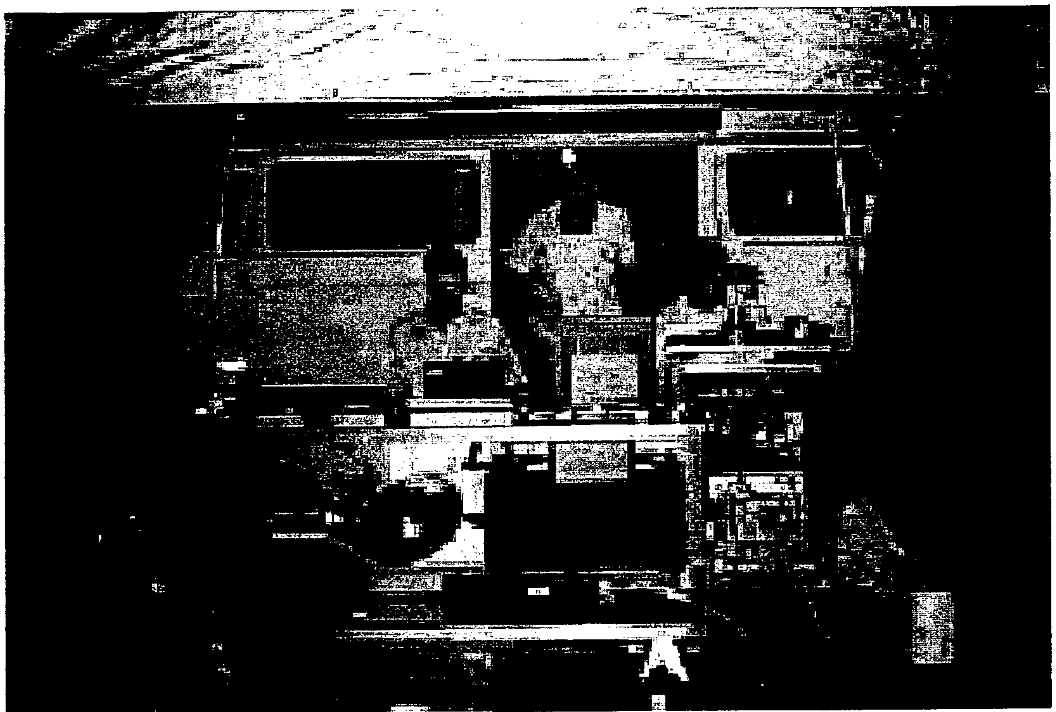


Figure 23.2 STI engineers with active DFI in field at Barber's Point

Figure 23.3 Ships in Pearl Harbor as imaged by the passive device of DFI from an aircraft

Optimized for shallow-water applications, DFI is the perfect tool for littoral applications such as bathymetry, coral discrimination (see image of fluorescing coral, above), object detection, and high-resolution spatial mapping. The instrument is designed to detect benthic pollutants, effluents, and surface obstacles, all of which require the unique combination of both systems. Both the passive hyperspectral imaging system and the active laser scanning system are integrated in one package, which can be installed in a light twin-engine aircraft in just a few hours. An integrated three-axis active stabilization system, in combination with a tightly coupled GPS/INS system, ensures fast and reliable geo-registration of the data. The DFI instrument provides a unique capability designed specifically for detecting, localizing, and identifying underwater objects.

DFI features three-axis image stabilization, science-grade high-speed CCD 12-bit dual camera system, compact, high throughput spectrometers, INS and GPS tight coupling, a navigation aid, and a simple operator interface. DFI provides high spatial resolution data (0.3 m2 per pixel), high spectral resolution visible reflectance data (up to 288 channels, 1.3 μm width), fluorescence excitation to discriminate and observe objects, geo-registration, a large area coverage rate, and quick turnaround from data collection to product.

Figure 23.4 The DFI/HIS Instrument chassis as mounted under the aircraft

Figure 23.4 shows the DFI/HIS Instrument chassis as mounted under the aircraft. Direction of flight is to the left. The left module is the dual hyperspectral spectrograph/camera heads. The center section supports the DFI scan mirror with the DFI receiver telescope and laser head to the right.

23.5 PRODUCTS

23.5.1 Commercial Products

This unique combination of passive HyperSpectral Imaging and active Laser Imaging Radar (LIDAR) fluorescence imaging provides superior discrimination of targets in coastal waters. The instrument can be flown on an aircraft and can quickly map large coastal areas. The images provide identification and location of mines and ordnance in shallow waters, including camouflaged targets. The system is ideal for environmental status mapping of pollutants, vegetation types, water quality, biota, and coral reef health status. The system may be sold as a product or STI may contract for services with the equipment developed and assembled under these contracts.

23.5.2 Papers, Patents, and Disclosures

No invention disclosures or patents were filed based on this project. STI holds the hardware and software as proprietary knowledge and has acted to protect it as necessary. The following paper was presented about this work.

Passive Hyperspectral and Active Spectral Fluorescence Imaging with the Advanced Airborne Dual-Mode Sensor System (AADMSS). Greg Mooradian, Detlev Even, Brad Speer, Carl Johnson, Rick Holasek, Mark Voelker. International Symposium on Spectral Sensing Research (ISSSR), San Diego, California, December 13-19, 1997.

23.6 IMPACT

23.6.1 Job Creation

The FY95 contract supported portions of eleven positions at STI including managers, scientists, engineers, technicians, programmers, and administrators for a total of 4,931 labor hours and a total of $171,322 direct labor dollars. The bulk of the work was conducted by the technical staff. The FY96 contract supported portions of eleven positions at STI including managers, scientists, engineers, technicians, programmers, and administrators for a total of 6,380 labor hours and a total of $221,400 direct labor dollars. The bulk of the work was conducted by the technical staff.

When STI received its first CEROS contract in 1993, it employed around 17 full-time workers. As of the time of this report, STI employs 55 employees including 5 on the Big Island and 6 on Maui. STI projects growing to 100 employees within the next year, and the company is willing to establish satellite offices on the neighbor islands to accommodate skilled engineers who prefer to live outside Oahu. Also, STI seeks to hire Hawaii people who have been trained or work on the mainland and desire to return to a high-tech position in Hawaii.

23.6.2 Business Development

STI has received several government and DoD contracts to develop and implement its hyperspectral imaging devices. STI recently received nearly $12 million from the DoD for military applications and another $4 to 5 million from another government agency for medical imaging applications.

23.6.3 Residual Benefits to Hawaii

This product will be manufactured and marketed from Hawaii by a Hawaii corporation providing long-term income to the state. Applications in the medical field are likely.

23.6.4 Principal Investigator/Company Opinion

Working with CEROS is fabulous. The CEROS staff is professional and cooperative. The fixed price contract vehicle is good for the company, and it aids the company to be able to suggest the payment schedule based on project milestones. The ability to keep title to the technology is very valuable to the company.

23.6.5 Impact on Principal Investigator/Company

The CEROS contracts have formed the basis of all hyperspectral devices being developed and implemented by STI. STI has built a significant business in Hawaii and the CEROS-funded projects will generate nearly 90% of its business in FY99 with gross revenues on the order of millions of dollars per year.

23.7 TRANSITION

STI integrated the DFI with its Hyperspectral Imaging System to obtain the active imaging from DFI alongside the passive hyperspectral data.

DARPA GRANT NO. MDA 972-94-1-0010
FINAL TECHNICAL REPORT

24.0 Bioactive Marine Isonitrile Compounds from Hawaiian Sponges as Models for Synthetic Nontoxic Antifoulant and Antibiotic Agents

ABSTRACT

This exploratory work is based upon (1) the observations that some sessile marine organisms remain significantly free of biologically based fouling and (2) the speculation that such organisms possess chemical defenses against fouling organisms.

Synthetic Technology Corporation developed and tested synthetic isonitrile compounds based on the natural metabolite *isocyanopupukeanane*, isolated from the marine sponge *Ciocalypta* sp., for effective, nontoxic, antifouling activity against common ship fouling organisms typical of the Pearl Harbor marine community. These and closely related compounds were also be tested as antibiotics, particularly as inhibitors of microbial biofilm, which is suspected to play role in in biologically signaling suitability for settlement of larvae of significant marine invertebrate fouling organisms. The active compounds were incorporated using several techniques into marine paint and field tested in the ocean for antifouling activity using *Hydrodies elegans* (a calcareous tube worm) as a representative ecological receptor.

Synthetic Technology Corporation has demonstrated that several naturally occurring compounds have potentially significant antifouling properties. However, most successful results are from laboratory bioassay studies and the compounds' antifouling potential has yet to be reproduced in ocean trials of paint formulations. The challenge remains to carry the compounds' antifouling capability into a practical formulation which efficiently delivers the active ingredient to the host organisms over an extended period of time.

Contractor: Synthetic Technology Corporation
3615 Harding Avenue, Ste. 308
Honolulu, HI 96816
phone: 808-735-0422

Principal Investigator: Dr. Mark Hagadone
mark_hagadone@msn.com

Contract Number:	Contract Amount:	Funding Year:
39616	$155,055	FY95
41777	$326,553	FY96

Start Date:	Completion Date:
October 1995	December 1996
January 1997	March 1998

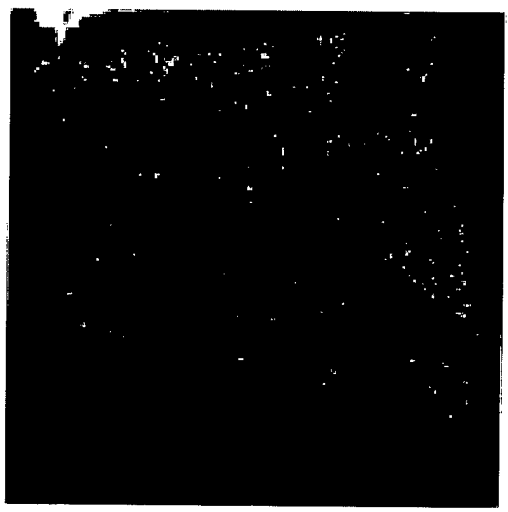
24.1 BACKGROUND AND TECHNICAL DESCRIPTION

24.1.1 Background

Biological fouling (biofouling) of ships' hulls causes drag that increases fuel costs, and degrades the structural integrity of the hull material. Figure 24.1 shows a test panel that is nearly covered by *Hydroides elegans* tubeworms after

just seven weeks in Pearl Harbor. Historically toxic heavy metals were added to marine paints to reduce biofouling. Due to increased environmental awareness and regulation, most of the effective additives now are prohibited by law. The DoD spends considerable resources on ships' maintenance that could be reduced if a nontoxic antibiofouling compound were identified and incorporated into marine paint.

***Hydroides elegans* is a problem biofouling organism in tropical and subtropical waters**



Panel immersed in Pearl Harbor for 7 weeks with nearly 100% cover by tubeworms

Figure 24.1

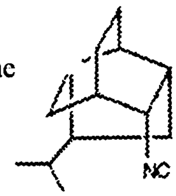
This exploratory work is based upon (1) the observations that some sessile marine organisms remain significantly free of biologically based fouling and (2) the speculation that such organisms possess innate chemical defenses against fouling organisms. The researchers chose metabolites isolated from the Hawaiian sponge, *Ciocalypta* sp., as a model and source of chemical compounds to study.

24.1.2 Technical Description

Figure 24.2 shows the chemical structure of tertiary and linear natural (ICP) and synthetic isonitriles tested during this project. Isonitriles with tertiary structures such as ICP and ADM appear (*in vivo*) to be more effective in reducing settlement of larvae of the polychaete *Hydroides elegans.*

Isocyanopu

9 - isocyanopupukeanane



1 9-isocyanopupukeanane

The chemical structure of 9-isocyanopupukeanane and its analogs, isontriles 2, 3, 4 and 5

2 3 4 5

Figure 2. The chemical structure of 9-isocyanopupukear isonitriles 2, 3, 4 and 5

R-NH$_2$ + CHCl$_3$ ⟶ R-

R =

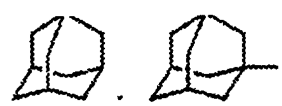


Figure 3. Reaction of primary amines with chloroform

R-Hal + AgCN ⟶ R-NC

R =

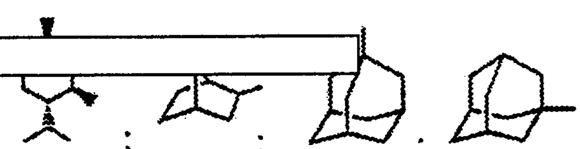


Figure 4. Reaction between cyanide ions and alkyl halid

R-NH-C(=O)-H ⟶ R-NC
7

24.2 OBJECTIVES

This project sought to develop and test one or more synthetic isonitrile compounds based on the metabolite *isocyanopupukeanane*, isolated from the marine sponge *Ciocalypta* sp., that could be an effective, nontoxic, antifouling agent against common ship fouling organisms typical of the Pearl Harbor marine community. These and closely related compounds would also be tested as antibiotics, particularly as inhibitors of microbial biofilm, which may be a key to settlement of larvae of significant marine invertebrate fouling organisms. The active compounds would be incorporated into marine paint and field tested for antifouling activity.

24.3 PROJECT ENVIRONMENT

Synthetic Technology scientists worked in their labs and offices located in Kaimuku and at the Kewalo Marine Basin, both on Oahu.

24.4 METHODOLOGY AND RESULTS

Synthetic Technology Corporation set out to identify potential antifouling compounds from the sponge *Ciocalypta* sp., focusing initially on the ICP isocyanopupukeanane. In FY95, isonitrile (ICP) compounds were extracted from field-collected sponges. Laboratory activity tests of both larval settlement and bacterial film development were monitored. As shown in Figure 24.3, the results indicated ICP at very low concentrations inhibits larval settlement without toxic effects. Also, biofilm development can dramatically impact effects of ICP in solution, with natural floral biodiversity impacted significantly. Initial field trials indicated that ICP and related compounds in a silicone coating reduce settlement of a variety of fouling organisms. Systematic errors in field bioassays artificially created by fish grazing were found to influence apparent biofouling test results, and Caged experiments were conducted to mitigate the effects. Some synthetic isonitriles apparently affect the ability of young fouling worms to develop calcium carbonate tubes. Laboratory bioassays indicated that ICP inhibition is related to inhibition of bacterial biofilm formation. ICP was shown to inhibit bacterial growth in biofilms by changing the inductive (propensity to settle) capacity of the films by lowering settling rates of biofouling larvae.

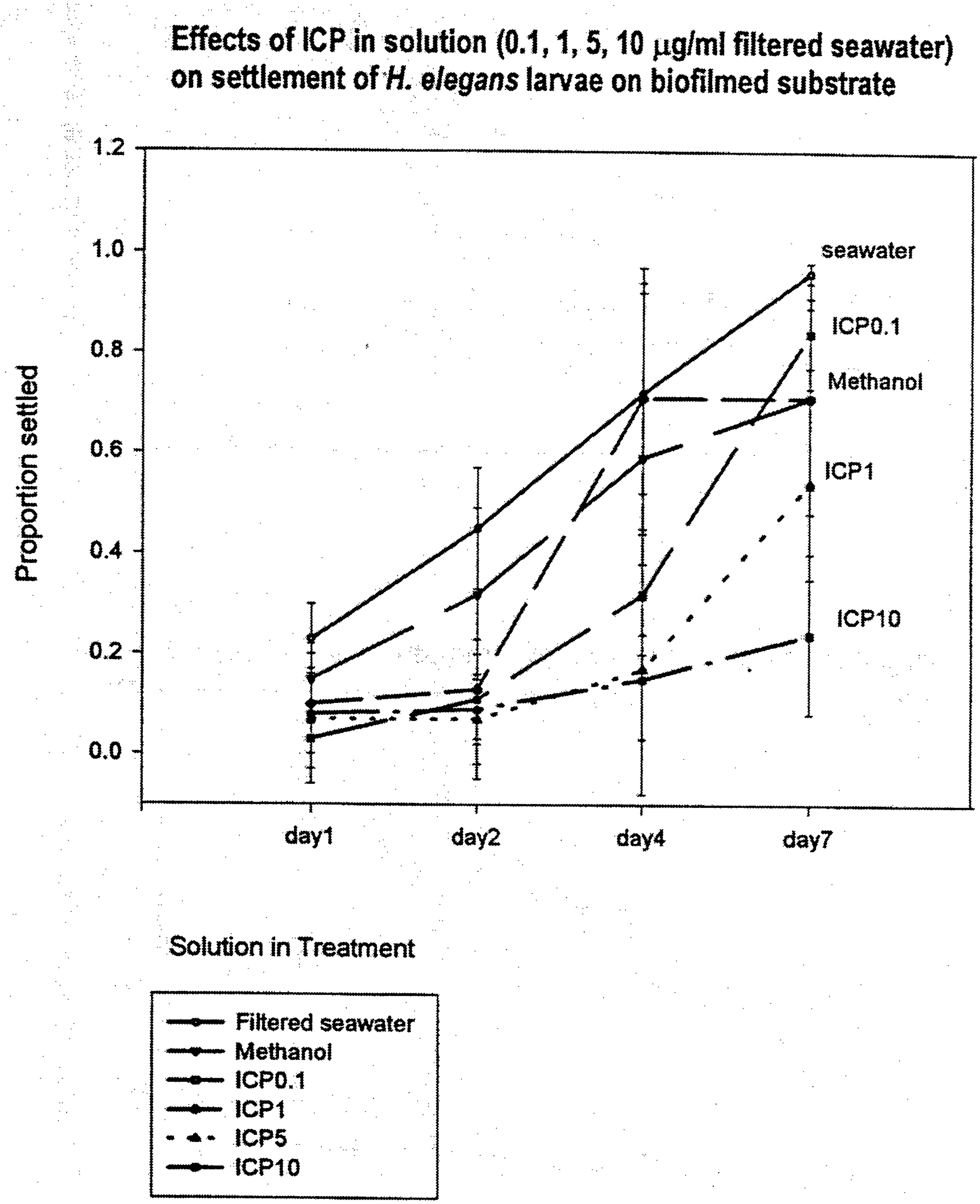


Figure 24.3 Effects of ICP in Solution

The focus of the FY96 effort was to (1) produce synthetic analogs of the isonitrile compounds, (2) incorporate the compounds in paints as antifouling agents, and (3) investigate the compounds' ability to inhibit biofilm formation. (Biofilm refers to bacterial surface colonization, a suspected precursor required for larval settlement and subsequent "macro" fouling). Synthetic Technology conducted (1) laboratory bioassays using common biofouling tubeworm larvae

and (2) field trails with paint preparations on fiberglass rods. They conducted additional tests with ICP derivative compounds from various marine organisms, and with synthetic isocyanoadamantane (ADM).

In laboratory studies, synthetic isonitrile compounds with simple linear structures were less effective than more complex, cyclic forms (such as natural isocyanopupukeanane). The synthetic ADM is a tertiary isonitrile and it strongly inhibited laboratory larval survival rates by causing tube disintegration when larvae settled, as shown in Figure 24.4. Test results confirmed dramatic reductions in tubeworm settlement with low concentrations (<10 parts per million on a weight / volume basis) of ICP and ADM. Both natural and synthetic products showed antibacterial properties and significantly reduced the development of single-species biofilms. In addition to the natural and synthetic isonitrile compounds described above, a natural product of coral (*Proites compressa*) was shown to reduce tubeworm settlement.

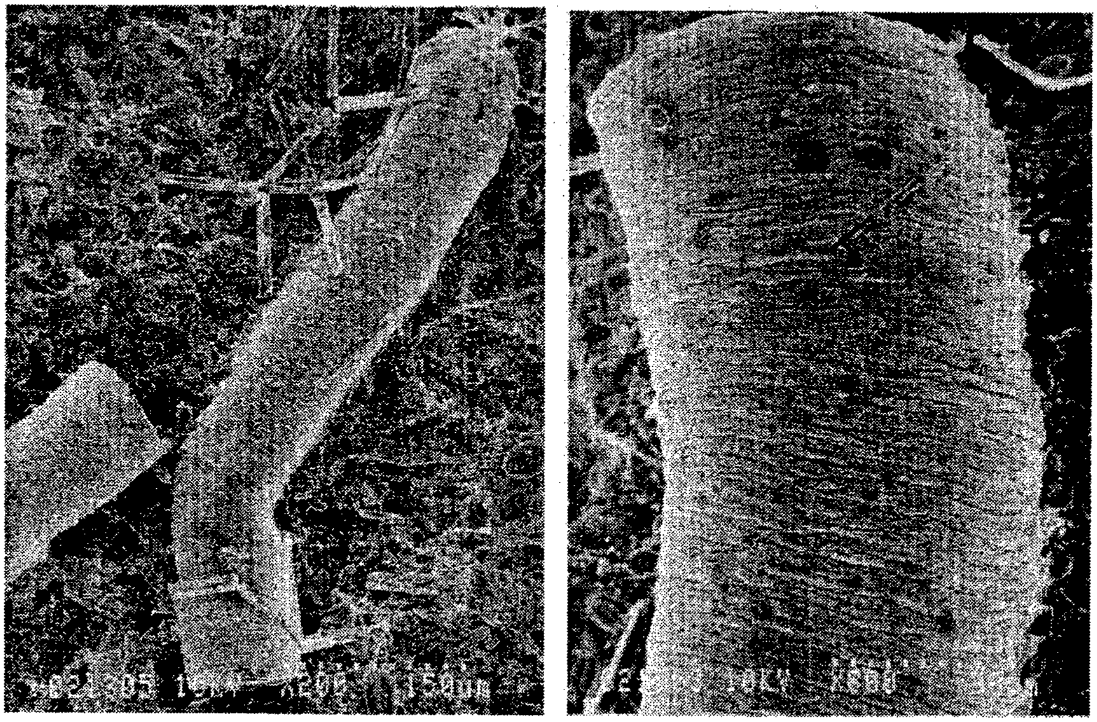
For the ocean situated antifouling paint studies, three different concentrations of ICP were mixed into silicon or epoxy paints and tested. A reactive isonitrile silicone monomer was synthesized, mixed into GE RTV11 silicone resin, and polymerized for tests as a coating in Pearl Harbor. Settlement on the ICP-containing paints did not differ significantly from the controls, as shown in Figure 24.5. Gross biofouling was not reduced by isonitrile silicon copolymers in paint, but a possible antibacterial effect on biofilm was noted. Field tests showed that ADM was lost rapidly from the silicone paint coating and was immeasurable in the surface after 7 days.

Synthetic Technology Corporation has demonstrated that several naturally occurring compounds have potentially significant antifouling properties. However, most successful results are from laboratory bioassay studies and the compounds' antifouling potential has not been demonstrated in the field tests of paint formulations. The challenge remains to effectively deliver the compounds' antifouling activity to the potential receptor organisms.

24.5 PRODUCTS

24.5.1 Commercial Products

The planned commercial product, synthetic analogs of isonitrile metabolites of Hawaiian marine sponges, incorporated in paints as direct antifouling agents or as antibiotics to prevent pre-fouling biofilm formation, was not realized during these contracts.



Above images show normal tubes built over microbial biofilm without ADM
In the presence of ADM (2.5 ppm), tubes are weakened and eroded as seen below.

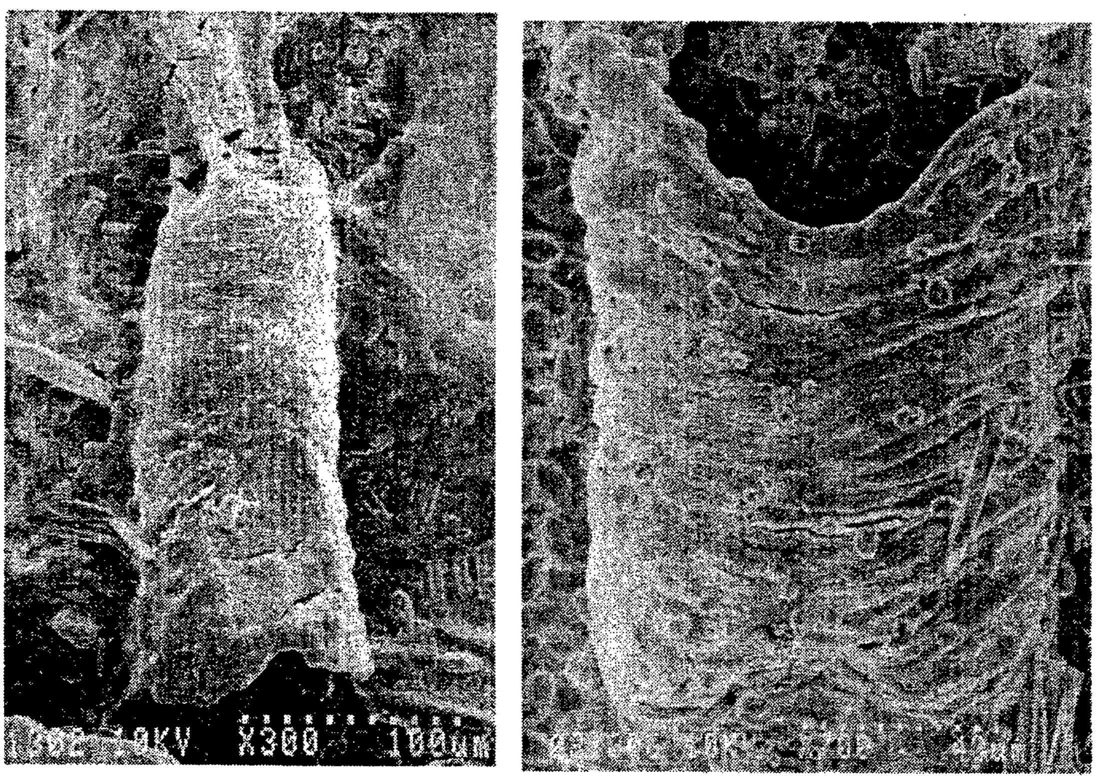
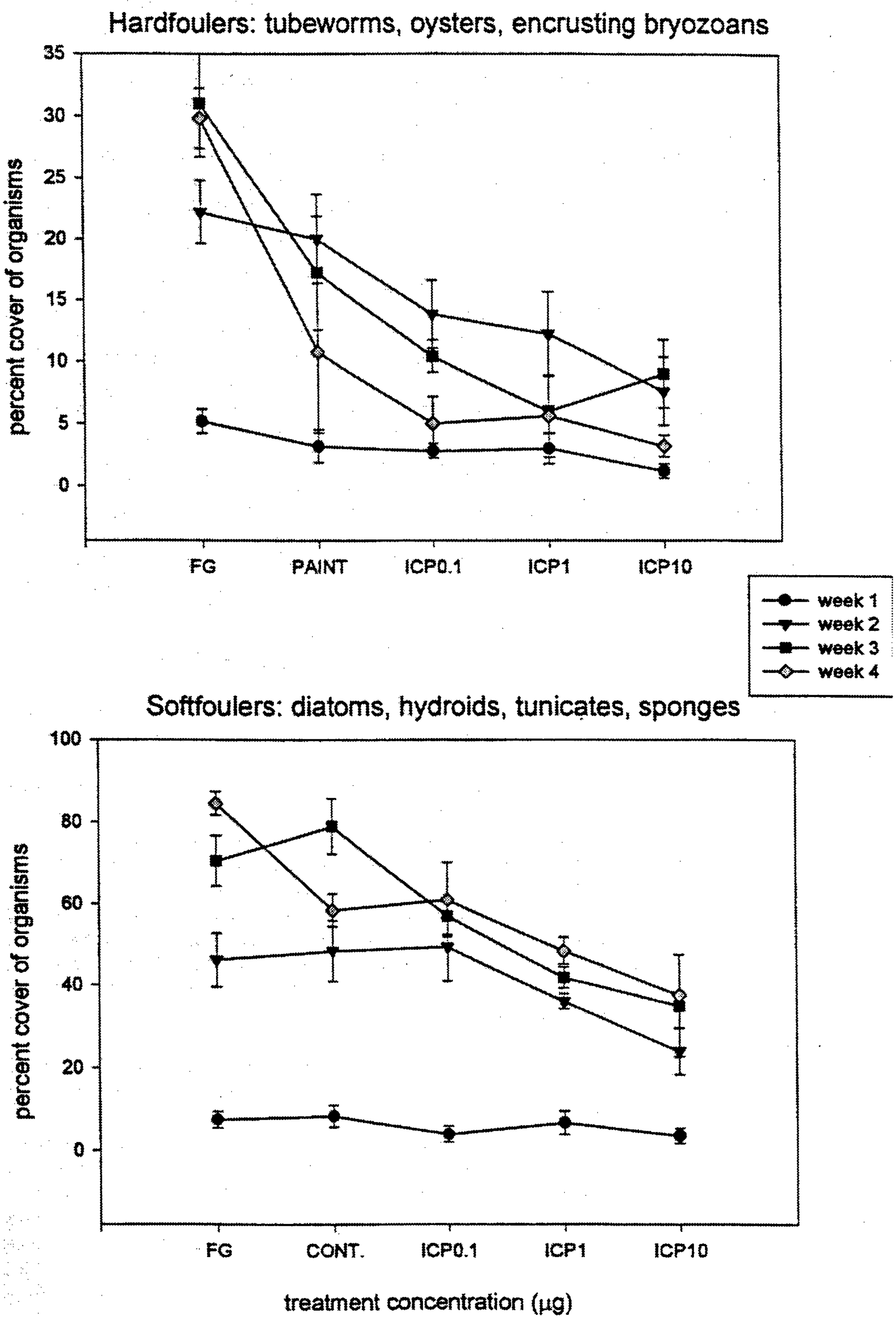


Figure 24.4

Figure 2: Field settlement of hard and softfoulers at Pearl Harbor on fiberglass rods coated with silicon foul release paint containing ICP.



24.5.2 Papers, Patents, and Disclosures

Synthetic Technology Corporation has a U.S. patent pending for "Isonitrile Anti-Fouling Agents" with application number 09/029,178.

Many papers and presentations were based on this work and the references are listed below.

Bioactive Marine Isonitrile Compounds From Hawaiian Sponges as Models for Synthetic Nontoxic Antifoulant and Antibiotic Agents. M.R. Hagadone. Proceedings of the Seventh (1997) International Offshore and Polar Engineering Conference (ISOPE 97), Honolulu, USA, May 25-30, 1997.

Effects of a Marine Isonitrile on Settlement of the Calcareous Tubeworm *Hydroides elegans.* C.R.C. Unabia, M. Hagadone, M Hadfield. International Symposium on the Settlement and Metamorphosis of Marine Invertebrate Larvae, Plymouth, U.K., July 1996.

Testing the Effects of Marine Isonitriles on Settlement of Fouling Organisms at Pearl Harbor. M. Hagadone. American Chemical Society, Hawaii Chapter, 1996.

Signals from Biofilms: Cues for Settlement of *Hydroides elegans,* C.R.C. Unabia, V.J. Paul, and M.G. Hadfield. Larval Biology Meeting, Melbourne, Australia, January, 1997.

Surface-Microbe-Invertebrate Interactions in Marine Biofouling. C.R.C. Unabia, Invited speaker, Gordon Chemical Conference on Marine Natural Products, Ventura, CA, February 1997.

Signals from Biofilms: Cues for Settlement of *Hydroides elegans.* Benthic Ecology Meeting, Florida Institute of Technology, Melbourne, Florida, March 1998.

Bioactive Marine Isonitrile Compounds from Hawaiian Sponges as Models for Synthetic Nontoxic Antifoulant and Antibioitic Agents. R.C. Unabia, M.R. Hagadone, M.G. Hadfield, X-Q. Gu, L. Lau and M.A. Tius. In: R.F. Brady and Y.S. Park (ed) Proceedings of the ONR US - Pacific Rim Workshop on Emerging Nonmetallic Materials for the Marine Environment, Honolulu, Hawaii, pp. 3-30 to 3-36, 1997.

24.6 IMPACT

24.6.1 Job Creation

The bulk of this contract supported labor hours because the contractor used existing in-house equipment. In FY95, this project supported a scientist and a student helper at 100%, and two other scientists and the principal investigator at 30% each for one year. Two outside consultants worked a total of 120 hours. The full-time positions were newly created for this project and have remained permanent to the time of this writing. In FY96, this project supported four scientists at 100%, a senior scientist at 70%, and the principal investigator at 80%. Outside consultants worked a total of 370 hours. The positions remained through out FY97 and were finally disbanded fiscal year 1999. No positions

remain and the joint research has ceased. The contractor believes that research is continuing at the Kewalo Marine Laboratory, funded by the State and the University of Hawaii.

24.6.2 Business Development

This research failed to develop a viable commercial product and failed in its attempt to create an additional, diversified business interest in the State of Hawaii.

24.6.3 Residual Benefits to Hawaii

The research has renewed and extended interest in biofouling activities at Kewalo Marine Basin where several of the preliminary "leads" developed by Synthetic Technologies are being carried on under State and University of Hawaii funding.

24.6.4 Principal Investigator/Company Opinion

The CEROS program was absolutely essential and vital for a small high technology company to probe and test the commercial viability of a laboratory based antibiofouling strategy. In spite of the "lack luster" end result which did not validate original hypotheses to the degree and extent expected, CEROS funding allowed this small local business to conduct first class research about a serious commercial problem with a potentially world wide application.

24.6.5 Impact on Principal Investigator/Company

The company and its staff were positively influenced by the process if not by the end result.

24.7 TRANSITION

CEROS funded a contract for $300,000 in FY97 to continue this work. Although a number of very interesting and challenging leads were developed, the bulk of the results of this applied research have been carried on by the State and University funded partner.

25.0 Development of an Underwater Video Camera for Optical Contrast and Range Enhancement Using Spectral Stretching

ABSTRACT

The objective of this project was to develop a working prototype of an underwater video camera with enhanced optical contrast, enhanced range performance, and real-time color video display for the diver (and surface monitor) using a technique termed "Spectral Stretching." A prototype was developed (the UCSS: Underwater Camera Using Spectral Stretching) and tested in a variety of underwater environments: shallow, deep (70 feet), clear, and turbid.

Research into the radiative transfer properties show that improved visibility and contrast to the human eye is possible if the nearly monochromatic (green) light at depth is split into narrow bands and re-imaged on a video screen as red, green and blue. A specially designed liquid crystal tunable filter (LCTF) and image intensified camera were enclosed in a watertight submersible housing and driven by computer control at video rates. The sequential images taken through each filter state of LCTF (at 30 Hz) were recombined as RGB for display.

Tests in shallow turbid water off Waimanalo show increased contrast performance relative to the eye and video camera. Tests in deep water off Hawai'i Kai show increased color contrast (compositional discrimination) over the eye, video camera, and color film.

The UCSS approach has potential applications in all underwater activities where optical range and contrast enhancement is important. The applications for the DoD and the private sector include environmental monitoring (e.g. coral reef species discrimination and health), inspection of underwater pipelines, communication lines, oil and gas well heads, pilings, moorings and piles, and surveys for unexploded ordnance or mines.

Recommendations for follow-on work include additional testing in more diverse environments, the development of an underwater computer (module) for miniaturization, the testing of different camera systems such as large dynamic range intensified CCD systems, and higher throughput LCTF. The spectral imaging techniques developed here can be applied to other underwater mapping and optical systems.

Contractor: Terrasystems, Inc.
2800 Woodlawn Drive
Suite 264
Honolulu, HI 96822
phone: 808-539-3745

Subcontractor: Sea Engineering, Inc.
Makai Research Pier
Waimanalo, HI 96795

Principal Investigator: Dr. Jonathan Gradie
Email: jgradie@TerraSys.com

Contract Number: 41358	Contract Amount: \$247,323	Funding Year FY96
Start Date: September 1996	Completion Date: June 1999	

25.1 BACKGROUND AND TECHNICAL DESCRIPTION

25.1.1 Background

Visual imaging is essential in many underwater activities including ROV navigation, underwater surveillance, condition inspections, damage assessment, and pollution and environmental monitoring. However, current visual imaging systems are often inadequate because of low light levels, loss of color perception, and the general loss of optical contrast and range by the spectral absorption, scattering, and turbidity characteristics of coastal and ocean waters. Engineers and divers often spend expensive field time photographing underwater sites only to find later that the images are deficient because of poor light levels, contrast, or object definition. Until now, research to improve underwater imaging systems has concentrated on increasing the light sensitivity of camera systems, using lasers for illumination, gating techniques to reduce scattering noise, and acoustic systems.

TerraSystems, Inc. (TSI) and Sea Engineering, Inc. (SEI) planned to develop an underwater video imaging system that uses spectral stretching to provide more usable images. Water absorbs light in the blue and red wavelengths so all that can be seen at depth is subtle shades of green. This loss of color contrast results in an essentially monochromatic system with reduced optical contrast. Color adds significantly to visibility by allowing the human eye to see the same shapes, forms, and positions under different contrasts. Objects that blend together in monochromatic light become visible when viewed in color. TSI and SEI will use spectral stretching to expand the subtle shades of green to a broad range of red-green-blue that the human eye can better discern. The visibility of objects will be improved by increasing the optical contrast.

25.1.2 Technical Description

The key components of the UCSS are shown in Figure 25.1 below. The three major subsystems are: 1) the submersible pressure housing, 2) the external (shipboard) computer, power supply and remote viewing monitor, and 3) the submersible cable linking the computer and pressure housing. An external view of the pressure housing and the cable is shown in Figure 25.2.

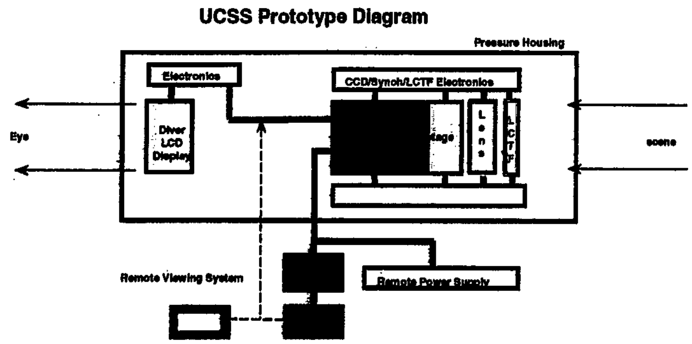


Figure 25.1 Block diagram of the UCSS major systems

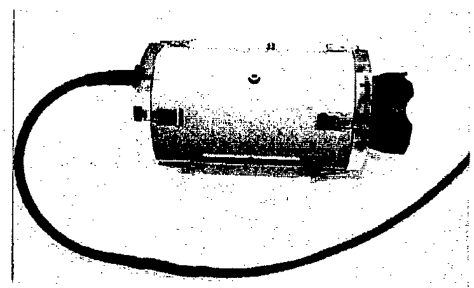


Figure 25.2 The UCSS pressure housing with cable attached

Internal to the pressure housing is the optical system (C-format lens, LCTF and image intensifier stage), supporting electronics, and a 4" x 5" LCD video display for the diver (Figure 25.3). These components were selected and designed to fit into the commercially available pressure housing.

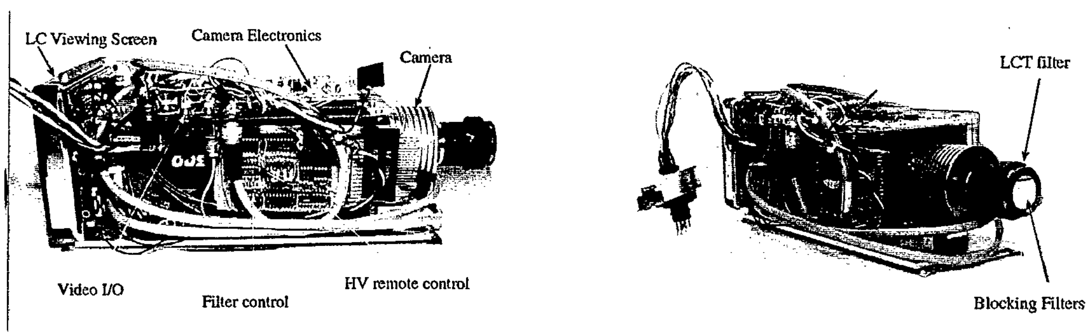


Figure 25.3 The configuration of the components in the pressure housing.

The spectral stretching is achieved by cycling the LCTF through three separate filter states (at approximately 490, 520 and 550 nanometers central wavelength) at 30 Hz. The Image intensifier stage then forms three separate back and white images at this video rate. These B & W images are combined in the frame grabber to form the color (RGB) image for viewing. The RBG image is updated at 10HZ since three cycles of the LCTF are needed for each color image.

25.2 OBJECTIVE

The objective of this project was to develop a working prototype of an underwater video camera with enhanced optical contrast, enhanced range performance and real-time color video display for the diver (and surface monitor) using a technique termed "Spectral Stretching." The prototype device, called the Underwater Camera (using) Spectral Stretching or UCSS uses an liquid crystal tunable filter (LCTF) to achieve the band sequential imaging spectral (color) separation. One objective was to determine the best filter band passes (narrow) in the green spectral region (near 550 nm) for underwater imaging.

The prototype was to be tested in a variety of underwater environments: Shallow (15 feet), deep (70 feet), clear, and turbid.

25.3 PROJECT ENVIRONMENT

The majority of the design and fabrication of the electronics, filter, computer, software and test equipment was performed at TSI offices in Manoa, Oahu. The pressure housing, testing support, staging and actual testing was done at SEI in Waimanalo, Oahu or with SEI boats and divers. Computer simulations of the radiative transfer environment done at TSI were sent to Mr. Charles Crandall at Displaytech (Boulder, CO) who assembled the LCTF.

The prototype LCTF was hand-delivered to TSI by Displaytech engineers who participated with TSI, SEI and University of Hawaii scientists and engineers in the tests and experiments with the LCTF to determine if the spectral characteristics would be suitable for the UCSS in underwater operation. Initial imaging tests were conducted by viewing the underwater environment in the giant saline tank at Sea Life Park using a test set up derived from the TSI inventory of cameras and electronics. These tests showed that the system would work but that quantitative testing was needed.

Field tests of the completed UCSS were performed in Pacific Ocean waters off Waimanalo (Oahu) at the Sea Engineering facilities at Makai Pier and in deep, clear water about two miles offshore of the Hawaii Kai (Oahu) area.

25.4 METHODOLOGY AND RESULTS

The UCSS transforms the subtle spectral radiance differences found in the underwater scene to the red, green and blue colors more discernable to the human eye. The fast (microsecond) electronically tunable nature of the LCTF allows this transformation, or spectral stretching, to be done in a "band-sequential" mode using only one camera. As shown in Figure 26-2, the output signal can be either (a) sent to a remote location (outside the pressure housing) for display, processing, or recording as a video signal; (b) digitized for digital display and processing at a remote location; or (c) transferred to a video screen for the diver.

Some results of the UCSS in operation are shown in Figure 25.4 below. These tests were performed in waters fifteen feet deep off Makai Pier in Waimanalo (Oahu). The sky was sunny; the water was turbid with fine silt and the illumination was coming from the left so that the targets were in partial shade.

The image on the left is recorded with a commercial video camera in a commercial underwater camera housing and shows the characteristics high scene brightness but low contrast for turbid water. The image on the right is from the UCSS situated next to the commercial video camera. The overall scene contrast is much larger because the excess light from the suspended sediments is not imaged (because of the narrow spectral bands). Also, the color contrast is much better because allowing for better discrimination between target materials.

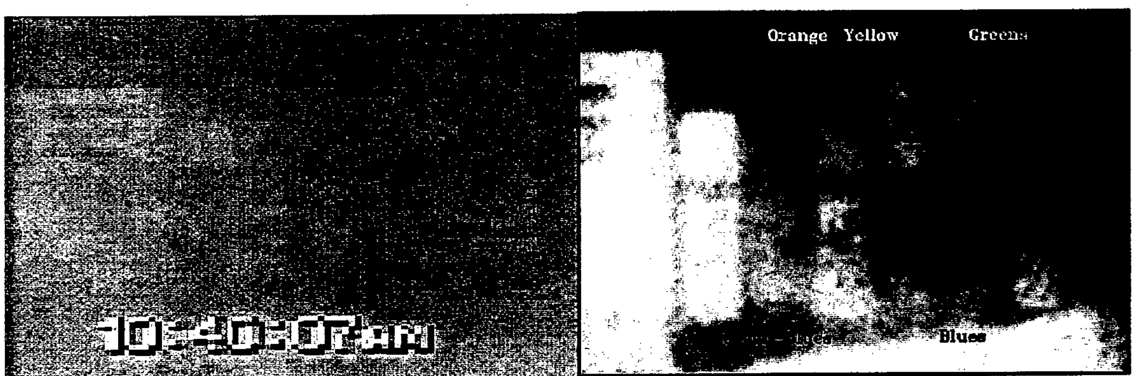


Figure 25.4 Comparison of commercial video (left) and UCSS (right) in shallow, turbid water with full sunlight.

Similar tests were performed at other depths. Figure 25.5 shows a comparison of the targets imaged with the commercial video camera and the UCSS at 70 feet in relatively clear water. The sun is shining into the camera (forward scattering arrangement) so that the target area is in shadow (no direct illumination). In clear water the overall scene brightness in both images is comparable because there is little scattering in the water (no haze). However, the UCSS image shows much better spectral contrast and discrimination among the target panels at a depth where a human's color perception has diminished markedly.

Figure 25.5 Comparison of a commercial video (left) and UCSS (right) at 70 feet depth.

In summary, the UCSS provides the enhancement in contrast as predicted. Moreover, the spectral stretching gives the diver the ability to discriminate between target materials from the residual color contrasts found in the nearly monochromatic environment at depth.

25.5 PRODUCTS

25.5.1 Commercial Products

A working prototype underwater video camera was developed and demonstrated under this contract. This camera features spectral stretching to provide better images than are produced with other types of underwater cameras. The investigators plan to improve the camera, and begin manufacturing and commercial sales when the product is ready for market.

25.5.2 Papers, Patents, and Disclosures

No papers or patents have been produced to date. TSI researched existing patents and determined that a patent was not worth the investment.

25.6 IMPACT

25.6.1 Job Creation

The bulk of this contract, nearly $182,000, supported labor costs (i.e. jobs) at TSI and SEI. Total workdays supported at TerraSystems was 250 days and included a principal engineer, optical engineer, electrical engineer, technical assistance, and project administration. Due to the CEROS contract, TSI created a half-time engineer. TSI sought other contracts to make this a permanent position. The follow-on contract led TSI to hire another engineer (PhD student)

at half-time and this position will become full-time with NASA money that TSI pursued due to the CEROS contracts. The subcontract to Sea Engineering supported a total of 72 workdays and partially supported a principal engineer, ocean engineer, and marine technician.

25.6.2 Business Development

The development of the UCSS has been synergistic with the airborne multi-spectral imagery services provided by TSI. The spectral imaging technology developed by TSI for land and coastal surveys has gained from the radiative transfer calculations. TSI has improved their ability to image deeper underwater as a result of the UCSS camera development. In addition, the success of the UCSS to see better underwater has led TSI, in conjunction with Prof. Charles Fletcher of the University of Hawaii, to investigate what new and unique oceanographic imaging tools can be developed for coastal zone mapping, especially for coral. An underwater mapping camera system is contemplated.

25.6.3 Residual Benefits to Hawaii

Successful creation of innovative technology enhances Hawaii's reputation as a leader in ocean resources instrumentation and ocean engineering tools. When the prototype is further developed into a commercial product, several jobs will be created for the manufacturing and sales.

25.6.4 Principal Investigator/Company Opinion

The principal investigator opined that the CEROS program is unique when compared to similar funding programs for several reasons. The program offices are in the state, and the CEROS administrators take a close personal interest in the projects. CEROS funds can be used to purchase parts and supplies to build prototypes in addition to supporting labor hours. CEROS encourages business and economic success as well as technical success. The CEROS spirit supports business development and economic benefit to the individual contractors and the state of Hawaii overall. The principal investigator considers it a capital investment made by an outside party and the company is committed to earning a return on investment.

25.6.5 Impact on Principal Investigator/Company

The CEROS funding helped stabilize TSI during the development of new commercial business and led to new product lines. TSI has transferred technology from aerial remote sensing to underwater applications. TSI's capability and credibility grew due to the CEROS work. TSI received other contracts based on the CEROS experience and TSI continues to apply for more.

25.7 TRANSITION

TSI was awarded a follow-on CEROS contract for the Underwater Mapping Camera, which is a direct result of the UCSS and TSI airborne multi-spectral camera development. Also, The CEROS-sponsored work led TSI to apply for other DoD SBIR topics (results of these applications were not available at the time of this writing).

Due to the CEROS work, TSI sold a $350,000 camera to Space Imaging Corporation, and won over $100,000 in service contracts from the University of Hawaii and the U.S. Army Corps of Engineers. In addition, TSI transitioned the technology to agricultural applications.

26.0 Development and Testing of a Clathrate Desalination Research Facility

ABSTRACT

Desalination is the process of producing potable water from seawater. The clathrate desalination plant is based on two fundamental principles: (1) when seawater freezes, salt is excluded from the ice crystal so freshwater may be obtained from the ice, and (2) clathrates are a class of chemicals that can crystallize or "freeze" water at temperatures well above the normal water freezing point. This project sought to design, build, operate and test a high pressure crystallization facility and a water purification and clathrate recovery system at the Natural Energy Laboratory of Hawaii Authority (NELHA) as an adjunct to an existing desalination pilot plant. Preliminary research by Thermal Energy Storage, Inc. (TESI) indicated that fresh water by clathrate desalination can be produced at a cost of $0.53/m^3 ($2.00/1000 gal.).

Makai Ocean Engineering, Inc. designed and constructed the high-pressure clathrate/water crystallizer at NELHA. The clathrate forming chemical is HCFC R141b (dichloromonofluoroethane (CCL_2FCH_3). The crystallizer houses the seawater phase change and separation to freshwater ice and excluded salt slurry. Makai learned that water from the 3000' depth at NELHA provided a sufficiently low temperature for natural clathrate formation. Tests showed that clathrates were formed spontaneously, and that the high pressure had little affect on the freezing temperature.

Thermal Energy Storage, Inc. designed and assembled the water purification-clathrate recovery system and integrated it with the pilot plant. TESI operated the Clathrate Desalination Pilot Plant intermittently over a period of several months. The system did not perform to design specifications and relatively small quantities of clathrate ice were produced. The water produced had a salinity of about 500 ppm total dissolved solids, the EPA's potability limit. The results validated the concept of a clathrate desalination plant.

All of the elements of the plant functioned as intended except for one subsystem, the wash column, which was to collect and wash brine from the surface of the clathrate crystals. Engineering and testing work done since completion of the CEROS funded work indicates that the drain area of the wash column must be increased substantially to make the system operational.

Contractor: Thermal Energy Storage, Inc.
6362 Ferris Square, Suite C
San Diego, CA 92121
phone: 619-453-1395

Subcontractor:
Makai Ocean Engineering, Inc.
P.O. Box 1206
Kailua, HI 96734

Principal Investigator: Mr. Richard McCormack
ramco@incom.net

Contract Number: 41367

Contract Amount: $250,000

Funding Year FY96

Start Date: October 1996

Completion Date: January 1999

26.1 BACKGROUND AND TECHNICAL DESCRIPTION

26.1.1 Background

There is a critical worldwide need for new fresh water sources. A recent report by the World Bank stated that the "world will have to spend $600 billion over the next decade to augment water reserves as demand spurred by urbanization and agriculture outstrips available supplies."

Desalination is the process of producing potable water from seawater. The clathrate desalination plant is based on two fundamental principles: (1) when seawater freezes, salt is excluded from the ice crystal so freshwater may be obtained from the ice, and (2) clathrates are a class of chemicals that cause crystallization or "freezing" of water at temperatures well above the normal water freezing point. Preliminary research by TESI indicated that fresh water by clathrate desalination can be produced at a cost of $0.53/m^3 ($2.00/1000 gal.), and that the cost would be competitive with water collection and storage systems in Southern California.

The Department of Defense can apply the technology to supply low-cost fresh water to floating platforms or to shore-based facilities in arid locations with access to cold ocean water at depth. The system is compact, and the process is simple and comparably economical. For example, the U.S. Navy is currently barging fresh water to its San Clemente Island training facility at a cost of $9.25/m^3 as compared to $0.53/m^3 ($2.00/1000 gal.) for the clathrate desalination process. Also, the cold, deep ocean water can be used to air condition the facility.

26.1.2 Technical Description

The Clathrate Desalination Pilot Plant is comprised of a crystallizer where the seawater freezes, a subsystem where the clathrate crystals are separated and washed and the crystals are melted, and a subsystem where the clathrate forming chemical is removed and recovered. The clathrate forming chemical is HCFC R141b (dichloromonofluoroethane (CCL_2FCH_3). A block diagram of the clathrate desalination plant is shown in Figure 26.1.

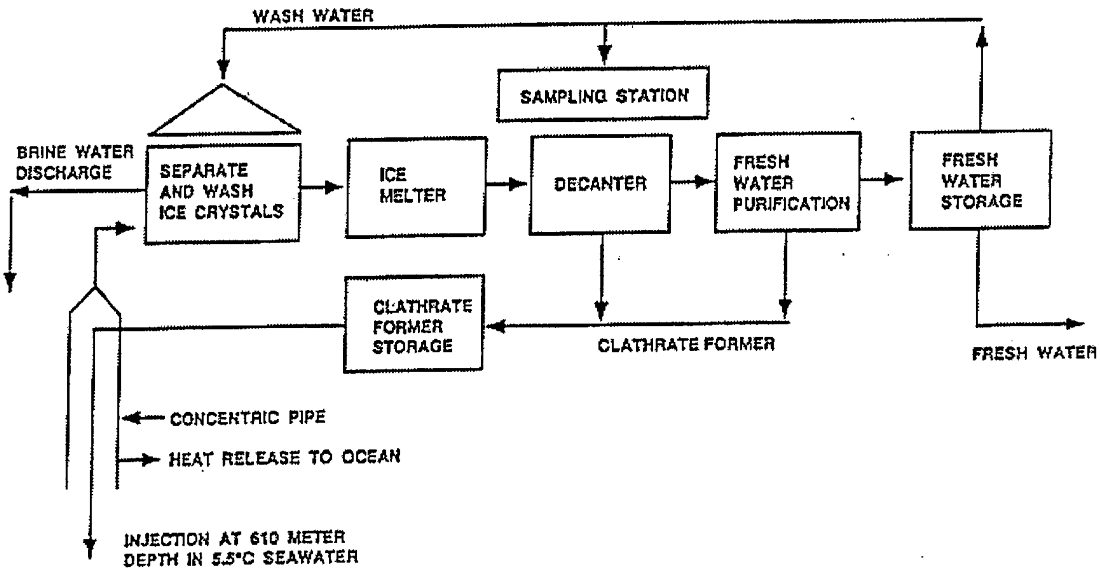


Figure 26.1 Block Diagram of the Clathrate Desalination Plant

26.2 OBJECTIVES

This project sought to design, build, operate and test a water purification and clathrate recovery system at the Natural Energy Laboratory of Hawaii Authority (NELHA). The system would use cold, deep seawater, high pressure, and a clathrate to reduce the energy required to freeze seawater, and then produce potable water from the ice. The result would be fresh drinking water at a commercially-viable cost of $0.53/m^3.

26.3 PROJECT ENVIRONMENT

Design and engineering was of the pilot plant and the clathrate recovery subsystem was conducted at the Thermal Energy Storage Inc. (TESI) offices in California and at Keahole Point, Hawaii. A high pressure crystallizer for research into the effect of deep-ocean pressures was designed and fabricated by Makai Ocean Engineering Inc. (Makai) facilities at Makai Pier, Oahu. The clathrate desalination pilot plant is located outdoors at the Natural Energy Laboratory of Hawaii Authority, Keahole Point, the island of Hawaii, Hawaii.

26.4 METHODOLOGY AND RESULTS

The deep-ocean water available at the Natural Energy Laboratory of Hawaii Authority (NELHA) has a temperature below the clathrate formation temperature. Consequently the clathrate can be formed without a mechanical

refrigeration system. The crystals formed are then separated and the surface seawater and salt is washed from them. The washed crystals are melted and the product water is released. The clathrate former is recovered from the product water by gravity separation and vacuum distillation. The clathrate former is then stored for reuse. The clathrate forming chemical is HCFC R141b (dichloromonofluoroethane (CCL_2FCH_3).

The CEROS work scope was comprised of four major tasks.

(1) Design, fabricate, and install a high-pressure crystallizer test apparatus.
(2) Operate and test the high-pressure crystallizer for performance under simulated deep ocean conditions.
(3) Design, procure, and incorporate a water purification and clathrate recovery system into the NELHA research facility (pilot plant).
(4) Operate the clathrate desalination pilot plant to measure the performance of the water purification and clathrate former recovery system, and to determine the optimum conditions for producing fresh water in an economical manner.

Tasks 1 and 2 were subcontracted to Makai Ocean Engineering while TESI performed tasks 3 and 4. Both companies shared in reporting tasks.

Tasks 1 and 2

The original plan for the high-pressure crystallizer was to simulate 610 meter (2000 ft) water depth with a pressure of 900 psi. At NELHA this depth can provide seawater at a temperature of approximately 6ºC (43ºF). However, preliminary testing showed Makai that the seawater temperatures at this depth were not low enough to promote rapid clathrate crystallization but that temperature of 4ºC (39ºF).would provide sufficient subcooling. Seawater that cold is available at NELHA at a depth of 915 meters (3,000 ft.) Therefore, a 3000' (1340 psi) deep-water crystallizer was designed and tested. The test apparatus incorporated a high-pressure crystallizer, view ports, a high pressure accumulator/injector reservoir, an R141b injection system, a flow sampling system, a mixing pump, a circulation pump, and temperature and pressure gauges. Makai assembled and operated the test facility at NELHA.

Operation of the crystallizer demonstrated that R141b clathrates were formed in significant amounts at 1340 psi and 4° C water temperature. At least 10 minutes of residence time in a heat exchanger was required to remove the clathrate heat of fusion and achieve clathrate conversion. Also, to initiate cystallization there must be some sub-cooling and vigorous mixing or other means to break up the clathrate former into very small, well-dispersed droplets. The high pressure provided almost no benefit as the formation temperature of R141b clathrate lowered only a tenth of a degree from 6.7° C to 6.6° C. High pressure may affect crystal size or conversion rate but these factors were not tested.

Tasks 3 and 4

Initially, TESI planned to use an air stripper in conjunction with a condenser and activated carbon filter for the water purification and clathrate recovery system. However, evaluation showed that the air stripper was power intensive and required additional clathrate former recovery steps. Consequently, TESI implemented a vacuum distillation design that removed R141b from the water by evaporation and condensation, with considerably less energy use. Figure 26.2 shows a photograph of the vacuum tower installation.

The final design of the recovery module is shown in Figure 26.3, and Figure 26.4 shows photographs of the completed system on-site. Water exits the freshwater decanter, is pumped into the top of the vacuum tower, and then is sprayed downward from the top. The water flows downward through the vacuum tower and into an internal reservoir that provides sufficient head to a low-head forwarding pump. The water level is controlled manually by observing the level through view ports set at the design level. The forwarding pump recirculates 80-90% of the water through the vacuum tower, and the balance flows to the activated carbon filters. The vacuum in the tower is maintained with a positive displacement vacuum pump at about 27 in. Hg. The vapor pressure of R141b is substantially higher than water, so it is evaporated at a much higher rate. The R141b and water vapor exiting from the vacuum pump is condensed, and R141b is returned to storage. The 10-20% of the flow from the forwarding pump is directed to the activated carbon filters. The activated carbon reduces the R141b concentration sufficiently to meet potability standards. The R141b recovery target was 99.9997%. The activated carbon reduced the R141b concentration below the detection limit of 250ppb achieved by the laboratory employed for the analysis. A concentration of 250 ppb translates to a recovery rate of 99.99966%. Thus the recovery module performance was better than the target level.

TESI operated the Clathrate Desalination Pilot Plant intermittently over a period of several months. The pilot plant did not operate as expected for a variety of reasons but with minor deviations from nominal, the clathrate former recovery subsystem operated as designed. Initially, the vacuum tower pressure was too low and air had to be added to the tower to maintain the correct pressure. The flowrates during the tests also were lower than planned. During the test it was necessary to adjust the valves to throttle the flow from the forwarding pump to avoid overwhelming the transfer pump from the storage tank. When the valves were fully open, the pressure from the forwarding pump caused flow backwards into the storage tank. One result of this was that the recycle flow fraction was less than the design level and this would tend to raise the concentration level in the flow at the inlet to the carbon filter. The piping was modified after the test so that the product (or test) water flows into the inlet of the forwarding pump. This change should achieve the design flowrates, but was not tested.

The results validated the concept of a clathrate desalination plant. More engineering and testing is needed before the system can be made operational.

Figure 26.2 Vacuum Tower Installation

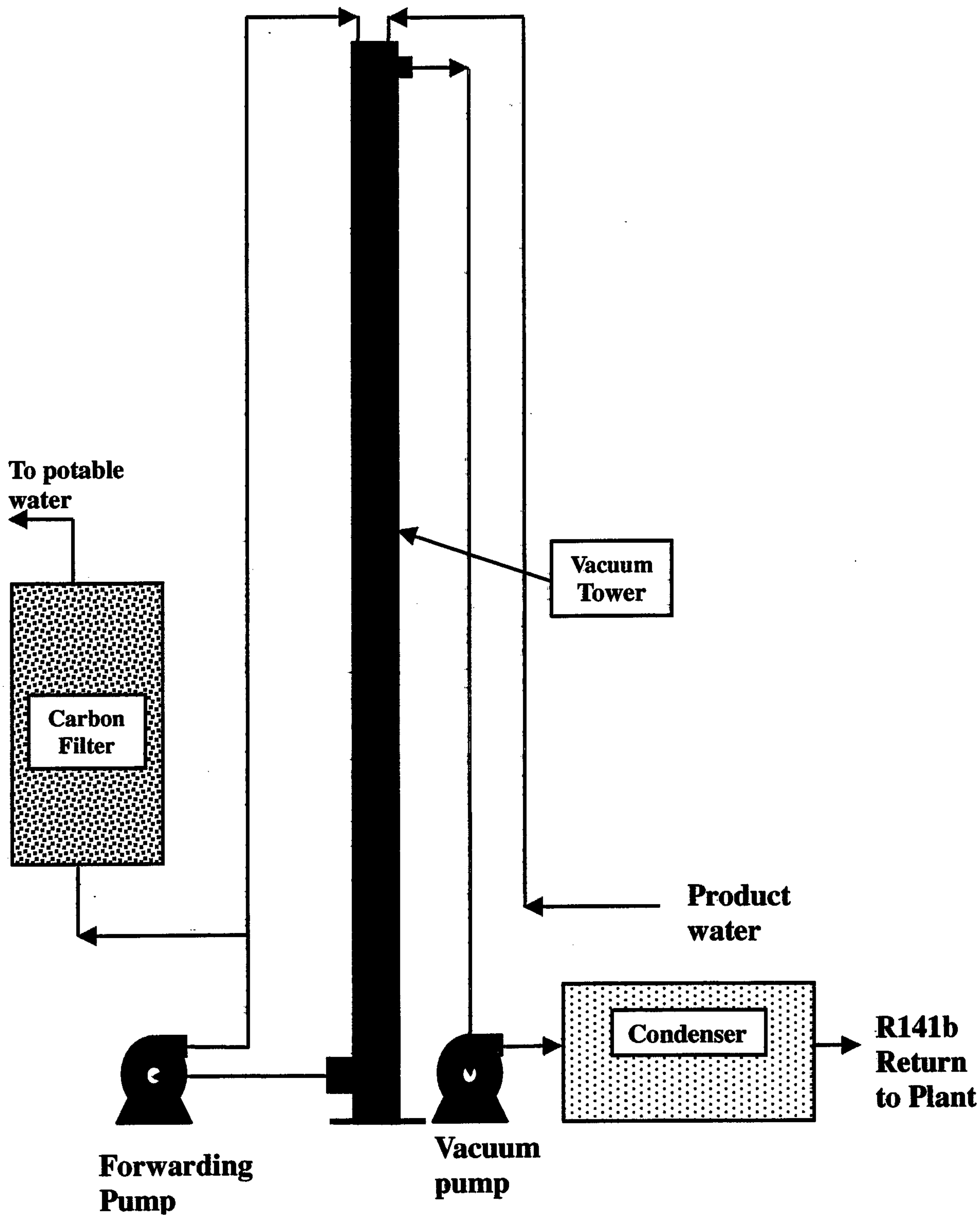


Figure 26.3 Final Design of the Recovery Module

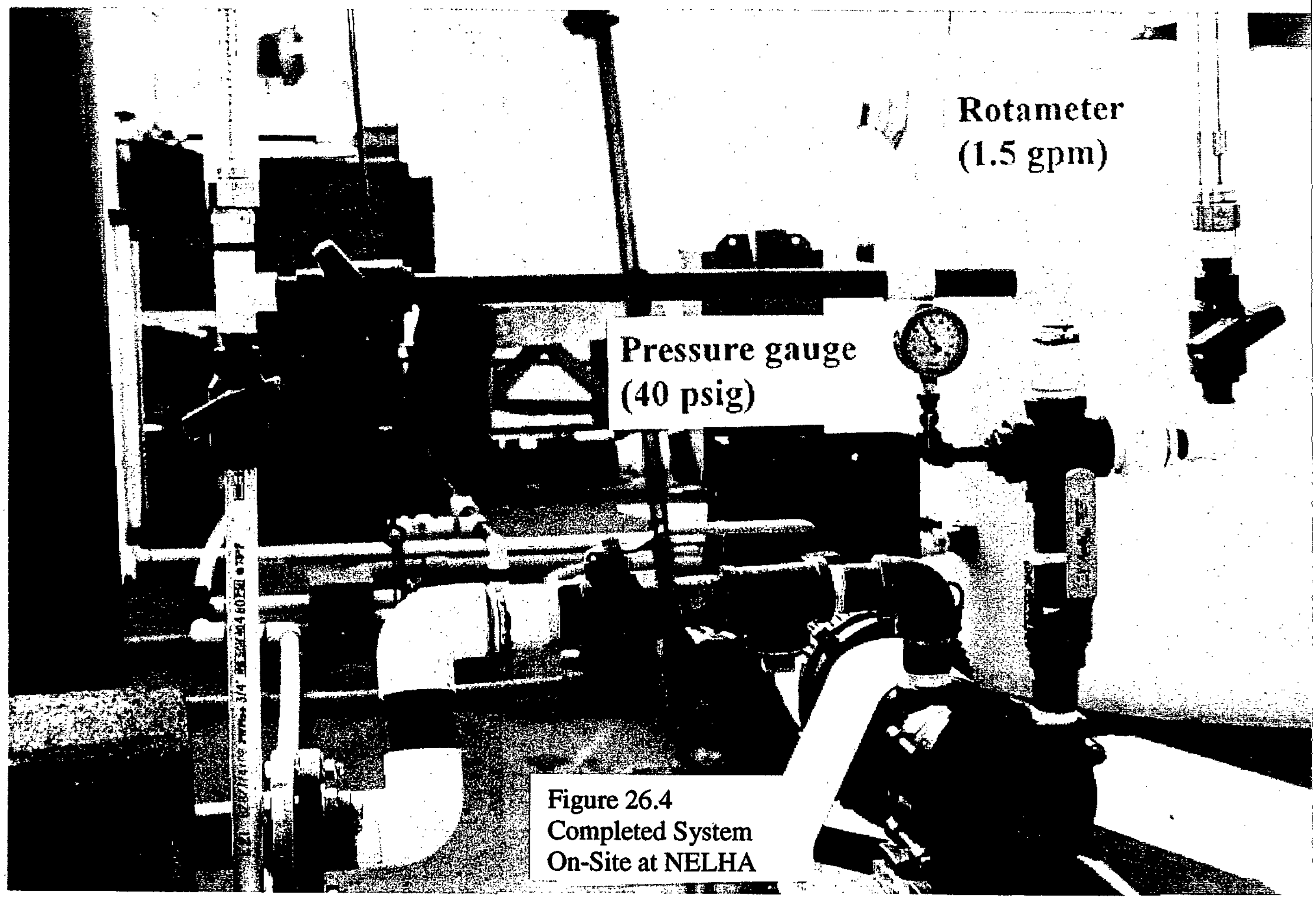


Figure 26.4
Completed System
On-Site at NELHA

26.5 PRODUCTS

26.4.1 Commercial Products

This project aimed to produce high-quality, potable water from seawater by an economically feasible method. No commercial product has resulted to date as this technology is in the early development and prototyping stage, but the work has shown the technical feasibility of the process, reducing the salinity in small quantities to approximately 500 parts per million.

26.4.2 Papers, Patents, and Disclosures

There were no papers, patents, or invention disclosures from this work. A patent was received by TESI based on earlier work supported by the Bureau of Reclamation. The work under the CEROS contract did not lead to a patent.

26.5 IMPACT

26.5.1 Job Creation

This contract supported parts of several ocean engineer and marine technician jobs for a total of 2,324 hours. The labor was split 1/3 to TESI and 2/3 to Makai.

26.5.2 Business Development

Thermal Energy Storage, Inc. has completed an evaluation of the pilot plant experiments, including subcontracted engineering studies of the wash column to determine the design changes needed to achieve design-level performance. In addition, the company has been seeking a strategic partner for further design and development work, and has held discussions with several companies.

26.5.3 Residual Benefits to Hawaii

This contract supported portions of several high-tech jobs at Makai, and the company benefited from working on a cutting edge ocean engineering project with funding from the Bureau of Reclamation. The California prime contractor purchased services, equipment, and hardware, in addition to the expenditures of per diem funds in Kailua-Kona while working on-site. The company estimates approximately $200,000 was spent in Hawaii. A local Kailua-Kona technician still works a few hours per month at the site as of the time of this writing. The company is at present discussing a contract with the NELHA to resume testing at the pilot plant.

26.5.4 Principal Investigator/Company Opinion

The project was very valuable to the continuing development of the clathrate desalination process. The CEROS staff was cooperative and helpful, and provided valuable technical advice.

26.5.5 Impact on Principal Investigator/Company

The CEROS project provided the means for designing, testing, and evaluating the recovery of the clathrate former (R141b) from the product water. The economics of the process are critically affected by the effectiveness of the recovery of the clathrate former because it is a relatively expensive chemical. The work done under the CEROS project resulted in a redesign of the recovery subsystem to make it more effective, and testing under the projected established the performance of the subsystem. The high pressure testing confirmed that the clathrate former would produce a clathrate when injected under conditions simulating the deep ocean conditions that would be experienced in an operating plant.

26.7 TRANSITION

CEROS did not award follow-on funding to this project. TESI entered into a cost-sharing agreement with the Bureau of Reclamation for this project in 1996, under which the Bureau provided $270,000 and the company contributed $180,000 for the construction and operation of a pilot plant. CEROS provided additional funding for testing clathrate formation at pressures equivalent to operation in the deep-ocean, and for clathrate recovery from the crystals. In 1999 the company entered into another cost sharing agreement with the Bureau of Reclamation in which the company and the Bureau each provide $100,000 for further research and development work.

27.0 Laser Heterodyne Imaging For Shallow Water Surveillance

ABSTRACT

Varian Associates, Inc. developed a proof-of-concept imaging system for object identification in very turbid waters (visibility range 50-80 cm). The Varian system obtained images with millimeter resolution at a range of over 10 attenuation lengths. The Varian prototype system exceeded the range and resolution capabilities of all existing optical systems for imaging in highly turbid waters.

To achieve the technological breakthrough demonstrated with the prototype laser imaging system, Varian used long wavelength (683nm) illumination, coherence gating, and heterodyne detection. The resulting system produced exceptional resolution and images in highly turbid waters during laboratory tests and demonstrations. The tests were run on a specially built underwater optical bench at the Varian facility in specially mixed water that duplicated the optical properties of highly turbid seawater in the littoral zone.

Under CEROS sponsorship, Varian created a novel laser heterodyne system and achieved unprecedented image resolution in very turbid seawater. Under CEROS FY97, Varian improved the unique heterodyne imaging system for object detection in littoral waters.

Contractor: Varian Medical Systems
Ginzton Technology Center
2599 Garcia Avenue
Mountain View, CA 94043-1111
phone: 650-623-1280

Subcontractor: Oceanit Laboratories, Inc.
1100 Alakea Street
31st Floor
Honolulu, HI 96813
phone 808-531-3017

Principal Investigator: Dr. M. Leonard Riaziat
majid.riaziat@grc.varian.com

Contract Number: 39615
Contract Amount: $299,674
Funding Year FY95

Start Date: October 1995
Completion Date: March 1997

27.1 BACKGROUND AND TECHNICAL DESCRIPTION

27.1.1 Background

Optical imaging in shallow, littoral waters is difficult due to the turbidity of the water caused by suspended sediments, organic matter, and other material in the water. The commercial systems currently available do not meet DoD and nonmilitary needs for surveillance of ships' hulls, piers, and bridges, and mine identification in bays and coastal areas. This chapter summarizes the first year of work funded by CEROS for the laser heterodyne imaging system.

Varian Associates, Inc. (Varian) of Palo Alto, California designed and prototyped an optical imager for turbid waters. Subcontractor Oceanit Laboratories, Inc. (Oceanit) of Honolulu, Hawaii, created a turbidity standard from natural materials for use in Varian's electronics lab where the instrument was built. The performance of the Varian system exceeded the range and resolution of all existing optical systems. Visibility is enhanced by a factor of 4 to 6. The system is optimized for very turbid waters with typical visibility of 50 to 80 cm (1.6 to 2.6 ft.) with objects at a range of 2 to 3 m. The system may be optimized to operate in different water types.

27.1.2 Technical Description

The system uses long wavelength illumination, coherence gating, and heterodyne detection which are novel techniques in underwater imaging. The light source is a compact 683 nm semiconductor laser that Varian modified to improve its coherence properties. The power consumption of the laser is 5W. The detector features balanced heterodyne detection that increases the sensitivity many times over a conventional detection system. The system works equally well in daylight or darkness.

27.2 OBJECTIVES

27.2.1 Project Objectives

The objective of this project was to design and test an underwater optical imaging system for highly turbid waters that have visibility of less than one meter. The investigators also strove to build a simple, compact, reliable system with low power consumption so that it can be operated as an autonomous unit.

27.2.2 Technical Objectives

The technical objective was to produce usable images in turbid waters such as are found in bays and littoral areas. To do so, the system must overcome the scattering effects of particulate matter, and interference from ambient light in turbid waters.

27.3 PROJECT ENVIRONMENT

The Principal Investigators conducted the imaging system development in the laboratory of Varian Associates located in Palo Alto, California. The prototype instrument rests on a lab bench in dry air with the imaging lenses looking through the side of a specially-designed tank of turbid water. Figure 27.1 shows the heterodyne imaging system as assembled on an optical table in Varian's lab. The target images are placed in the turbid water in the tank.

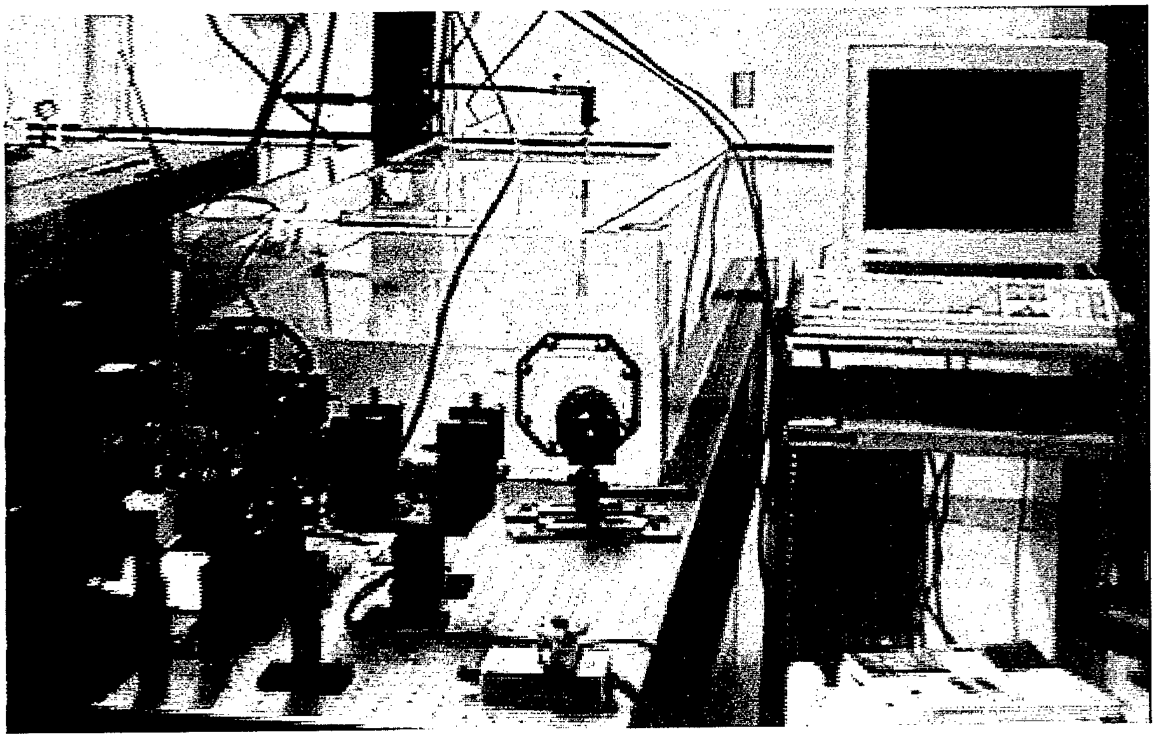


Figure 27.1 The heterodyne imaging system as assembled on an optical table.

Oceanit personnel worked in the field in Hawaii and in their geochemistry laboratory in Hawaii to develop the material for the turbidity standard. They shipped the concentrated material to Varian in California.

27.4 METHODOLOGY AND RESULTS

The methods can be summarized as follows. The water tank was designed and assembled. Natural turbidity concentrates were prepared and standardized. The imaging system model was written and verified. The wavelength was selected, and an appropriate laser identified and modified. A balanced heterodyne detector was constructed and optimized. Labview data was acquired and images were obtained. Finally, the performance was compared with other systems. The system operates equally well in ambient light or complete darkness, and significantly surpasses all other existing systems.

Turbidity Standard. Oceanit Laboratories, Inc. of Honolulu, Hawaii conducted this portion of the project. Turbid water was created in the lab using suspended material collected from natural waters in Hawaii. After testing samples from several locations, the investigators selected material from Kaelepulu Pond in Honolulu and prepared a standard that was used in all imaging tests by Varian. Concentrated material from the Pond was suspended in freshwater to simulate the turbid water of estuarine and littoral environments. This turbidity standard is more realistic than typical turbidity standards used in

labs such as diatomacious earth, polystyrene microspheres, Formazin, or antacid liquids.

Laser Source Wavelength Selection. An underwater optical imaging system needs to be tailored to the water type. This project created a system for turbid waters found in bays and coastal areas. The optical power in a beam of light propagating through water is attenuated exponentially by scattering and by absorption. Scattering and absorption vary with the wavelength of the light. Imaging through turbid water is limited by blurring rather than optical attenuation. In other words, in turbid water the limiting factor is scattering rather than absorption. Varian determined that longer wavelengths in the deep-red range are better than green or blue-green light when imaging in turbid water, as shown in Figure 27.2. The investigators found an SDL 7630 diode laser that met the requirements of the system. This laser operates at 680 nm wavelength, has a nominal output of 500 mW, and uses 5 watts of power. The wavelength is longer than typical underwater imaging systems, and Varian was the first to recognize the advantage and apply it.

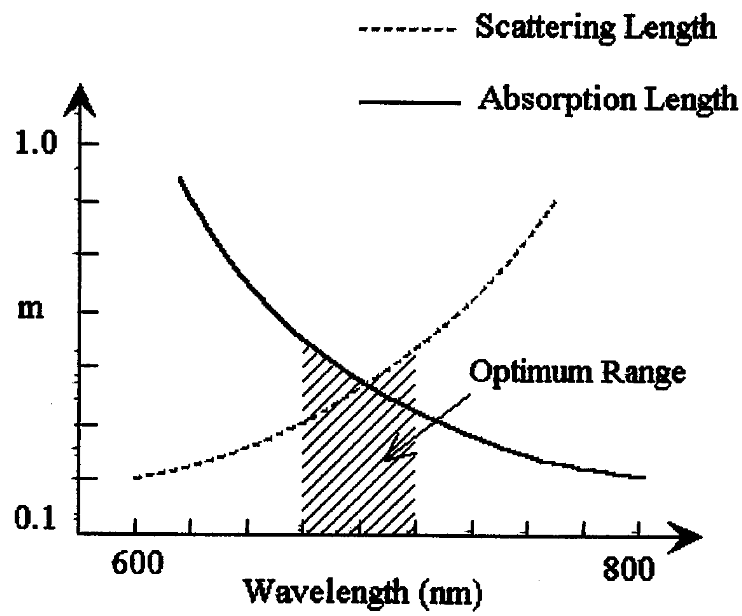


Figure 27.2 Scattering length and absorption length as a function of wavelength

Source-Light Coherence Gating. To minimize the blurring effect of back-scattered light, time-gating (or range-gating) is often used. A laser pulse illuminates the target, and the image detector (usually a camera) is gated on to record the image only after the light has had time to travel back from the target. The rest of the time the detector is gated off to prevent recording the back-scattered light. Pulsed lasers used for time-gating are larger and more expensive to operate than cw lasers. An alternative gating technique makes use of the finite coherence length of the cw laser output. By using a relatively short coherence-length laser, a gating effect similar to time-gating can be achieved. To optimize the SDL 7630 laser for coherence gating, Varian removed the frequency

selective diffraction grating from the laser cavity, and increased the length of the cavity. The heterodyne detector does the gating so no extra switching is needed. An added benefit of heterodyne detection is that the source laser can be changed between a pulsed laser and a short coherence-length cw laser without any other modification to the system.

Optical Heterodyne Detection. The system detector features balanced heterodyne detection that significantly increases the sensitivity over a conventional detection system. In heterodyne detection the received signal is mixed with a reference beam at an offset frequency, and the difference frequency is detected. Figure 27.3 shows a schematic of the heterodyne coherence gated laser imaging system. This allows the measurement of a very small signal in the pico-watt range, i.e. a few photons. Advantages of optical heterodyne detection are the elimination of ambient light interference, a higher signal to noise ratio than direct detection, increased dynamic range, automatic time/coherence gating, and suppression of dark current and laser power fluctuation noise by balanced detection.

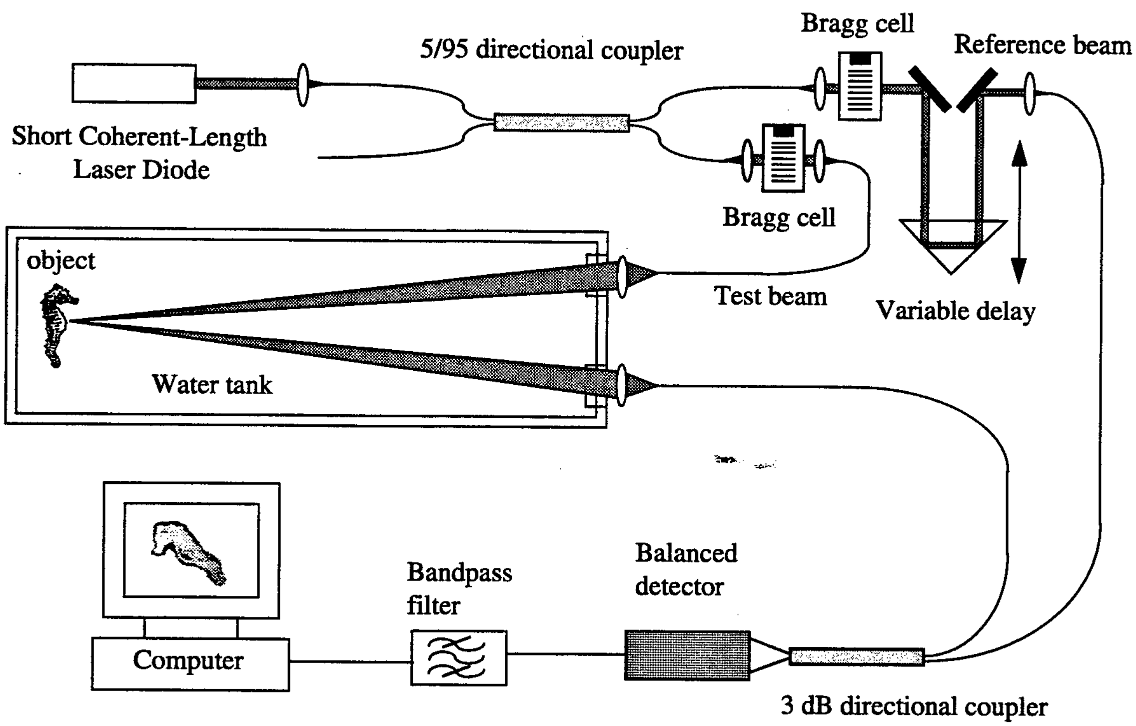
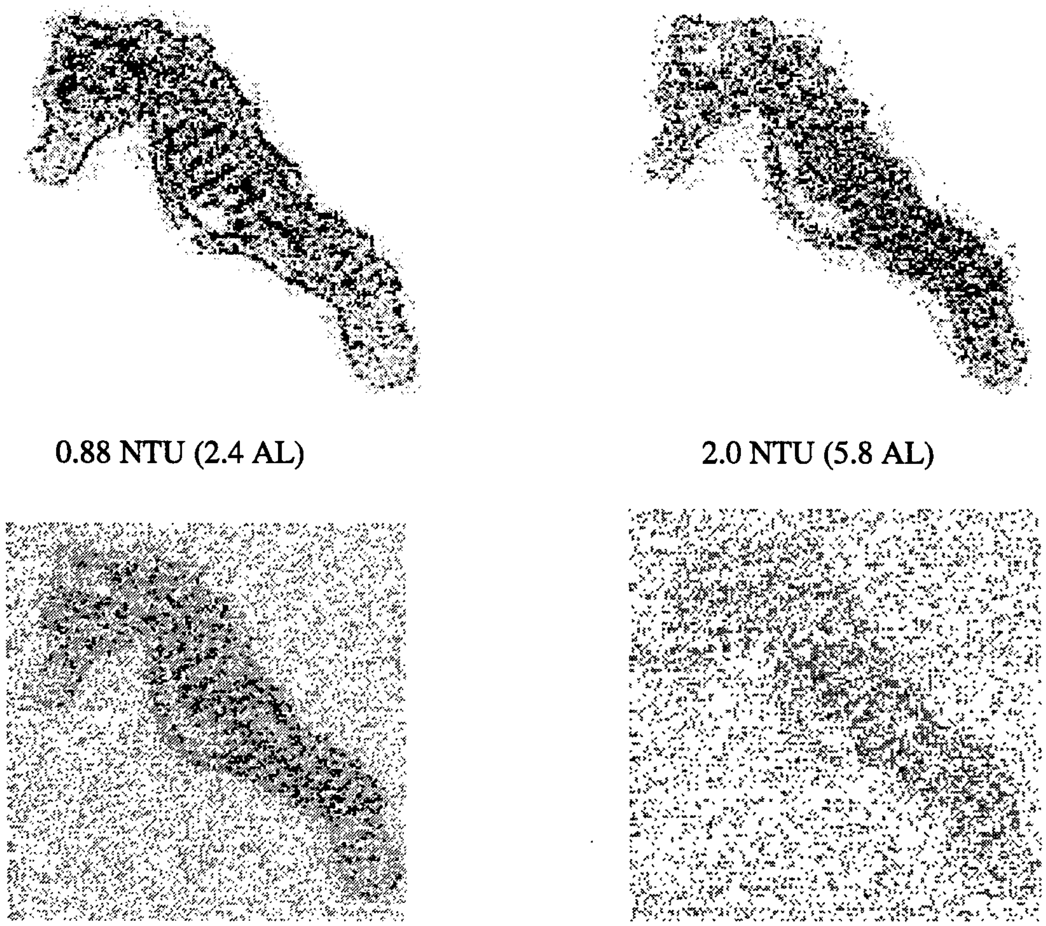


Figure 27.3 Schematic diagram of Varian's heterodyne coherence gated laser imaging system.

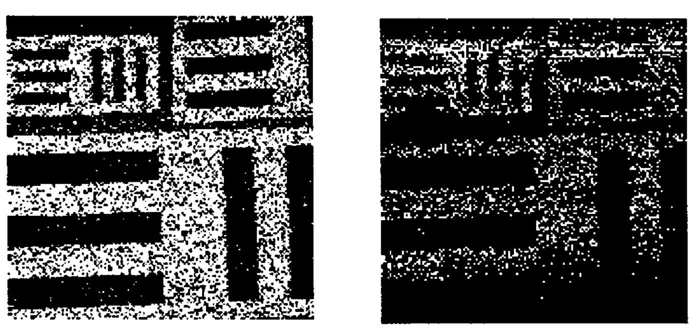
The results were remarkable. The prototype system obtained images with millimeter resolution at a range of over 10 attenuation lengths. The Varian system exceeded the range and resolution capabilities of all existing optical systems for imaging in highly turbid waters. Figures 27.4 and 27.5 show images scanned with the Varian system.



0.88 NTU (2.4 AL) 2.0 NTU (5.8 AL)

3.0 NTU (7.6 AL) 4.0 NTU (10.2 AL)

Figure 27.4 Scanned two-dimensional images of a rubber stamp target (sea horse).



(a) clear water (b) 11 AL

Figure 27.5 Images of the resolution target.

27.5 PRODUCTS

27.5.1 Commercial Products

No commercial products have resulted due to the early stage of technology development. Varian produced a working prototype that surpassed the performance of all comparable systems. However, it has not been adapted for underwater or in the field use. Varian anticipates potential commercial products for medical imaging, and it will allow its Hawaii partner companies to commercialize oceanographic applications.

27.5.2 Papers, Patents, and Disclosures

The principal investigator published one paper based on this work: "Laser Heterodyne Imaging for Shallow Water Surveillance." M.L. Riaziat, R.X. Cao, and L.C. Wong and R. Bourke. Proceedings of the Seventh (1997) International Offshore and Polar Engineering Conference (ISOPE 97), Honolulu, USA, May 25-30, 1997, pp. 544-549.

No patents have been filed. Novel and patentable features of the system are the use of coherence and wavelength optimization in underwater imaging. However, because these features were publicly disclosed in the paper mentioned above, they are no longer patentable. Varian determined that a patent was not economically beneficial.

27.6 IMPACT

27.6.1 Job Creation

Senior Engineers at Varian worked at least 1649 hours or 0.88 full time equivalent (FTE) on this project. Supporting staff contributed another 0.22 FTE to this project. The principal investigator, a long-term Varian employee, worked part-time on this project while conducting other projects. Varian hired one engineer to work on this project full-time. Due to a funding gap, Varian was not able to sustain this position after the CEROS contract. Small portions of other Varian positions were supported including a Varian librarian who conducted a literature search for the project. When Varian received follow-on funding from CEROS FY97, it hired another engineer who will remain a Varian employee after the completion of the CEROS project.

Under the subcontract to Oceanit Laboratories, Inc., one biologist worked for one month on this project. The CEROS funding helped sustain this long-term position in Hawaii.

27.6.2 Business Development

This project is at the prototype stage.

27.6.3 Residual Benefits to Hawaii

Hawaii benefited from the working relationships established with this cutting edge technology firm in California. Varian will look to Hawaii again in the future as a source of technical capabilities, and any potential commercialization of this technology will be done in collaboration with companies in Hawaii.

27.6.4 Principal Investigator/Company Opinion

The Principal Investigator contrasted his experiences with CEROS and other government agencies located in Washington, D.C.. He stated that CEROS is more efficient, more responsive, and has less bureaucracy. He found the Technical Director very accessible, and the other staff always helpful. The Hawaii subcontractor conducted good, technical work.

Working with CEROS and Hawaii engineering firms changed the Principal Investigator's image of Hawaii. He now knows that Hawaii companies have strong technical capabilities, and that a government agency in Hawaii can be effective and efficient.

27.6.5 Impact on Principal Investigator/Company

The CEROS funding provided an opportunity to develop a core technology that Varian can bridge to other technologies. The working relationships established with Hawaii companies will continue, and the Principal Investigator will seek other partnerships in Hawaii.

27.7 TRANSITION

Varian Associates received $395,000 in follow-on funding from CEROS in FY97. The results from the CEROS-sponsored work enabled Varian to apply to ONR and other agencies for additional development funding.

Varian is motivated by the commercial potential in the medical field because this technique may be suitable for imaging tumors. In follow-on funding from CEROS under FY97, Varian partnered with Detection Limit Technology, Inc. (DLT) of Kailua, Hawaii to improve the system and modify it for in-field use. DLT will receive the rights to commercialize the technique for oceanographic applications if it chooses to do so.

APPENDIX A
DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
GRANT NO. MDA 972-94-1-0010
May 25, 1994

ADVANCED RESEARCH PROJECTS AGENCY
3701 NORTH FAIRFAX DRIVE
ARLINGTON, VA 22203-1714

Grant No.:	MDA972-94-1-0010
ARPA Order No.:	A217/01
Effective Date:	25 May 1994

Grantor: Advanced Research Projects Agency
Contracts Management Office
3701 North Fairfax Drive
Arlington, VA 22203-1714
(Attn: John H. Ablard, 703/696-2383)

Grantee: High Technology Development Corporation (HDTC)
An agency of the State of Hawaii
Mililani Technology Park
300 Kahelu Avenue, Suite 35
Mililani, HI 96789

Total Grant Amount: $5,000,000

Accounting and Appropriation Data:

ACR: AA 9740400.1320 A217 P4G10 2525 DPAC 4 5136 503733 $5,000,000

Authority: This Grant is issued pursuant to the authority of 10 U.S.C. 2358.

GRANT SCHEDULE

1. Purpose: The purpose of this Grant is to support and stimulate a broad spectrum of research in ocean sciences in the State of Hawaii. This effort shall be carried out as generally set forth in the Grantee's proposal entitled: "Operational Plan, National Defense Center of Excellence for Research in Ocean Sciences (CEROS)" dated 16 February 1994, a copy of which is in the possession of both parties.

2. Term: The term of this Grant commences on 23 may 1994 and continues through 23 May 1996.

3. Terms and Conditions: This Grant is subject to the general Terms and Conditions set forth in the attached Exhibit A, entitled: "ARPA Grant General Terms and Conditions", and to any special terms and conditions in the Grant Schedule.

4. Project Officer: The Project Officer representing the Government under this Grant is Dr. Charles Stuart, ARPA/MSTO, Telephone:(703) 696-2315. The Project Officer shall also function as the ARPA Scientific Officer.

5. Administrative Grants Officer: The Administrative Grants Officer (AGO) for this Grant is the Office of Naval Research Resident Representative, California Institute of Technology, 565 SOuth Wilson Ave., Pasadena, CA 91106-0234.

6. Principle Investigator: The Principle Investigator, Mr. William M. Bass, CEO, HDTC, shall be responsible for this effort. The Grantee agrees to notify the Grantor before changing the Principle Investigator.

7. Grant Funding: This Grant is fully funded in the amount of $5,000,000.

8. Payments: Upon acceptance of the terms and conditions of this Grant and submission of an invoice or public voucher by the grantee to the AGO, the grantee shall be entitled to and initial payment of $400,000. This initial payment is expected to cover the work performed during the start-up efforts under the Grant. Subsequent payments will be initiated upon receipt of the Grantee's invoices by the AGO who will certify and transmit them for payment to the Defense Accounting and finance Center, Crystal Mall #3, Washington, DC 20371. Invoices shall be submitted in sextuplicate. Invoices, if necessary to pay required expenditures may be submitted in accordance with the following schedule:

Payment Number	Amount	Payment Date
1	$400,000	Upon Grant Execution
2	$2,000,000	1 October 1994
3	$900,000	1 January 1995
4	$900,000	1 April 1995
5	$550,000	1 July 1995
6	$250,000	Upon Grant Completion

9. Reports and Reports Distribution: Reports shall be furnished as specified below:

9.1 Report Types:

a. Quarterly R&D Status Report - This report shall keep the Government informed of Grantee activity and Progress toward accomplishment of Grant Objectives and advancement in state-of-the-art on the research and development involved. The report shall outline the CEROS's activities during the reporting period and detail its financial transactions and current fiscal situation. At a minimum, expenditures shall be sufficiently documentable to enable an auditor to track separately, the administrative expenses and those expenses associated with technical activities.

b. Special Technical Reports - These reports, due as required, shall document the results of a significant task, test, event or symposium.

c. Final Technical Report - This report, due upon completion of the Grant, shall document the result of the complete effort.

9.2. Report Distribution:

Addresses	Report Types	Number of Copies
Project Officer	All	Two
Administrative Grants Officer	All	One
ARPA/OASB Library	Final Technical Report	One
Defense Technical Information Center Attn: DTIC-DFAC Cameron Station Alexandria, VA 22304-6145	Final Technical Report	Two
ARPA/MSTO (Attn: Tom Griffin)	Quarterly R&D Status Report	One

10. Title to Property: Title to all real property and equipment purchased by the Grantee with grant funds shall vest in the State of Hawaii in accordance with the provisions of Office of Management and Budget (OMB) Circular A-102. Title to all equipment shall vest in the State of Hawaii upon acquisition.

11. Audit: The Comptroller General and the Inspector General of the Department of Defense shall have direct access to sufficient records and information of the Grantee, as they determine, to ensure full accountability for federal funds.

12. Uniform Administrative Requirements: This Grant is subject to OMB Circular A-102 "Uniform Administrative Requirements for Assistance to State and Local Government."

13. Uniform Cost Principles: This Grant is subject to the uniform cost principles of OMB Circular A-87.

14. Drug-Free Requirements: This Grant is subject to the requirements of the Drug-Free Workplace Act of 1988 and the Drug-Free Schools and Communities Act Amendments of 1989.

15. Competition Requirements: Prior to the execution of any sole source subcontract or sole source subgrant with an estimated value of $25,000 or more, the grantee shall submit the action to the Grant Officer for approval.

16. Revocation: Either party may terminate this Grant in whole or in part, upon notice to and consultation with the other party, and upon agreement of the other parties that continuation of the project would not produce beneficial results commensurate with the further expenditure of funds. In addition, the Grants Officer may revoke this Grant upon a finding that the Grantee has failed materially to comply with the provisions of the Grant.

FOR the United States of America,
the Advanced Research Projects Agency

By: ______________________
JOHN H. ABLARD
(Grants Officer)

May 25 1994
(Date)

For: CEO, High Technology Development Corporation(HDTC)
The Trustees of the State of Hawaii

Accepted By: William M Bass Jr
(Grantee)

Executive Director
(Title)

May 31, 1994
(Date)

EXHIBIT A - MDA972-94-1-0010

GRANT GENERAL TERMS AND CONDITIONS
FOR EDUCATIONAL INSTITUTIONS, NONPROFIT ORGANIZATIONS
AND STATE AND LOCAL GOVERNMENTS

<u>ARTICLE</u>

EXHIBIT A
MDA972-94-1-0010

1. Federal Requirements

This Grant is subject to the laws and regulations of the United States. If any statute expressly prescribes policies or specific requirements that differ from the requirements, standards, provisions, or terms and conditions of this Grant, the provisions of the statute shall govern.

2. Order of Precedence

Any inconsistency or conflict in the terms and conditions specified in this Grant shall be resolved according to the following order of precedence:

(a) The Grant Schedule

(b) Terms and Conditions in Exhibit A of this Grant

3. Administration and Cost Principles

Applicable to this Grant, and incorporated herein by reference, are the requirements, standards, and provisions of the appropriate OMB Circulars and attachments thereto, as revised as of the effective date of this Grant, listed below. For purposes of this paragraph, the term "appropriate" is determined by the organizational nature of the Grantee (educational institution, nonprofit organization, state or local government).

(a) A-110, "Uniform Requirements for Grants and Agreements with Institutions of Higher Education, Hospitals, and Other Nonprofit Organizations."

(b) A-21, "Cost Principles for Educational Institutions"

(c) A-122, "Cost Principles for Nonprofit Organizations"

(d) A-87, "Cost Principles for State and Local Governments"

(e) A-102, "Uniform Administrative Requirements for Grants- In-Aid to State and Local Governments"

(f) A-88, "Indirect Cost Rates, Audit, and Audit Follow-up at Educational Institutions"

4. Research Responsibility

The Grantee has full responsibility for the conduct of the research activity supported by this Grant, in accordance with the Grantee's proposal, and the terms and conditions specified in this Grant.

Grantees are encouraged to suggest or propose to discontinue or modify unpromising lines of investigation or to explore interesting leads which may appear during the development of the research. However, they must consult the Project Officer through the Administrative Grants Officer before significantly deviating from the objectives or overall program of the research originally proposed.

The Grantee is responsible for communicating results and open dialog via internet to the Project Officer during the entire period of performance.

5. Amendment of Grant

The only method by which this Grant can be amended is by a formal, written amendment signed by either the Grants Officer or the Administrative Grants Officer. No other communications, whether oral or in writing, are valid.

6. Prior Approvals (Universities only)

The provisions of this Article are applicable to universities only.

a. All prior approvals required by OMB Circulars A-21 and A-110 are waived hereby except for the following:

(l) Change of scope or objectives as required by Article 4 of the Terms and Conditions entitled "Research Responsibility."

(2) Change of key personnel as required by Article 7 of the Terms and Conditions entitled "Principal Investigator."

(3) Foreign travel as required by Article 17 of the Terms ant Conditions entitled "Foreign Travel Approval."

(4) Extension of the expiration period of this Grant.

b. Preaward Costs

(l) Grantees may incur preaward costs of up to ninety (90) days prior to the effective date of the Grant award.

(2) Preaward costs as incurred by the Grantee must be necessary for the effective and economical conduct of the project and the costs must be otherwise allowable in accordance with the appropriate cost principles.

(3) Any preaward costs are made at the Grantee's risk. The incurring of preaward costs by the Grantee does not impose any obligation on the Government, in the absence of appropriations, if an award is not subsequently made or if an award is made for a lesser amount than the Grantee expected.

c. Unobligated Balances

In the absence of any specific notice to the contrary, Grantees are authorized to carry forward unexpended balances to subsequent funding periods.

7. Principal Investigator

Support for the project may not continue without the active direction of the Principal Investigator (PI) approved for, and identified in, this Grant. If the approved PI (1) severs his or her connection with the Grantee, or (2) otherwise relinquishes active direction of the project, either permanently or for a significant length of time (three months or more), then the Grantee must either:

(a) appoint a replacement PI with the approval of the Project Officer, or

(b) relinquish the Grant, in which case the Grant shall be terminated for convenience in accordance with Attachment L of OMB Circular A-110.

8. Restrictions on Printing

Unless otherwise authorized in writing by the Grants Officer, reports, data, or other written material produced using funds provided by this Grant and submitted hereunder shall be reproduced only by duplicating processes and shall not exceed 5,000 single page reports or a total of 25,000 pages of a multiple page report. These restrictions do not preclude the writing, editing, preparation of manuscript or reproducible copy of related illustrative materials if required as a part of this Grant, or incidental printing such as forms or materials necessary to be used by the Grantee to respond to the terms of the Grant. To satisfy the requirements of the Defense Technical Information Center, at least one copy of each technical report submitted to the Defense Technical Information Center must be black typing or reproduction of black on white paper or suitable for reproduction by photographic techniques. Reprints of published technical articles are not within the scope of this paragraph.

9. Publication

Publication of results of the research project in appropriate professional journals is encouraged as an important method of recording and reporting scientific information. One copy of each paper planned for publication shall be submitted to the Project Officer simultaneously with its submission for publication. Following publication, copies of published papers shall be submitted to the Project Officer.

10. Acknowledgement of Sponsorship

(a) The Grantee agrees that in the release of information relating to this Grant, such release shall include a statement to the effect that (1) the project or effort depicted was or is sponsored by the Defense Advanced Research Projects Agency, (2) the content of the information does not necessarily reflect the position or the policy of the Government, and (3) no official endorsement should be inferred.

(b) For the purpose of this article, information includes news releases, articles, manuscripts, brochures, advertisements, still and motion pictures, speeches, trade association proceedings, symposia, etc.

(c) Nothing in the foregoing shall affect compliance with the requirements of the clause entitled "Security."

11. Grantee-Acquired Property

Title to all nonexpendable and expendable tangible personal property purchased by the Grantee with grant funds shall be deemed to have vested in the Grantee upon purchase, unless stated otherwise in this Grant schedule.

12. Patent rights

Patent rights are as specified in 48 CFR 227 and 252, as amended, and 37 CFR 401.14 of July 1, 1987, which titles and sections are incorporated herein by reference.

Invention disclosures are to be submitted to the Administrative Grants Officer who will forward them directly to the Counsel for Patent Matters, (Code OOCCl), Office of the Chief of Naval Research, Department of the Navy, Arlington, Virginia 22217-5000. The Counsel for Patent Matters will represent the Administrative Grants Officer with regard to invention reporting matters arising under this Grant.

13. Rights in Technical Data and Computer Software

Rights in Technical Data and Computer Software are as specified in 48 CFR 227 and 252, as amended, incorporated in this Grant by reference.

14. Human Subjects

Grant funds may NOT be used for research that uses uninformed or nonvoluntary humans as experimental subjects. The Grantee is responsible for the protection of the rights and welfare of any human subjects involved in research, development, and related activities supported by this Grant. The Grantee agrees to comply, as appropriate, with the following directive and regulations which are incorporated in the Grant by reference:

(a) DoD Directive 3216.2, DoD Directive 3216.2, "Protection of Human Subjects in DoD Supported Research," 7 January 1983;

(b) DHHS Regulations, "Protection of Human Subjects" (45 Code of Federal Regulations, Part 46) of 26 January 1981, as amended; and,

(c) FDA Regulations (21 Code of Federal Regulations, subchapters A, D, and H).

15. Animal Welfare

Any Grantee performing research on warm blooded vertebrate animals shall comply with the Laboratory Animal Welfare Act of 1966, as amended, (7 U.S.C. 2131 et seq.), and the regulations promulgated thereunder by the Secretary of Agriculture (9 CFR, Subchapter A, Parts 1 through 4) pertaining to the care, handling, and treatment of vertebrate animals held or used for research, teaching, or other activities supported by Federal awards. In addition, the Grantee shall comply with the provisions of DoD Directive 3216.1 and clause 52.235-7003 of the DoD Federal Acquisition Regulation Supplement.

The Grantee is also expected to ensure that the guidelines described in DHHS Publication No. (NIH) 85-23, "Guide for the Care and Use of Laboratory Animals," are followed and to comply with the U.S. Government Principles for the Utilization and Care of Vertebrate Animals Used in Testing, Research, and Training," included as an Appendix to the NIH Guide.

16. Research Involving Recombinant DNA Molecules

Any Grantee performing research involving recombinant DNA molecules and/or organism and viruses containing recombinant DNA molecules agrees, by acceptance of this award, to comply with the National Institutes of Health "Guidelines for Research Involving Recombinant DNA Molecules," Nov 1984 (49 CFR 46266-46291, or such later revision of those guidelines as may be published in the Federal Register.

17. Foreign Travel Approval

Foreign travel requires liaison with the Project Officer for advance approval. Grantee is cautioned that such advance approval could require 90 days in certain situations.

18. Activities Abroad

The Grantee shall assure that project activities carried on outside the United States are coordinated, as necessary, with appropriate Government authorities and that appropriate licenses, permits, or approvals are obtained prior to undertaking proposed activities. The awarding agency does not assume responsibility for Grantee compliance with the laws and regulations of the country in which the activity(ies) is (are) to be conducted.

19. Civil Rights Act

Grantees shall comply with the provisions of the Civil Rights Act of 1964, as amended, and implementing regulations, and the Assurance of Compliance which the Grantee must have on file prior to award of this Grant. Said Act, as amended, and regulations are incorporated in this Grant by reference.

20. Clean Air and Water

If the amount of the Grant exceeds **$100,000,** the Grantee shall comply with the Clean Air Act (42 U.S.C. 1857), as amended; the Water Pollution Control Act (33 U.S.C. 1251), as amended; Executive Order No. 11738; and the related regulations of the Environmental Protection Agency (40 CFR, Part 15). Said regulations, Executive Order, and Acts are incorporated in this Grant by reference.

21. U. S Flag Carriers

The Grantee shall comply with Section 5 of the International Air Transportation Fair Competitive Practices Act of 1974; the Comptroller General's Guidelines for Implementation of said Act, March 12, 1976; and Comptroller General's Decision B-138942, clarifying the guidelines. Such Act and guidelines are incorporated into this Grant by reference.

22. Security

The Grantee shall not be granted access to classified information under this Grant. If security restrictions should happen to apply to certain aspects of the proposed research, the Grantee will be so informed. In the event that the scientific work under this Grant may need classification, or involve access to or storage of any classified data, the Government shall make its decision on the need to classify, or require such access or storage, within 30 days after receipt of written notice from the Grantee. If the decision is affirmative, the Government shall invoke the clause in OMB Circular A-110, Attachment L, paragraph 4.b. entitled, "Termination for Convenience."

23. Officials Not to Benefit

No member of, or delegate to, Congress, or resident commissioner, shall be admitted to any share or part of this Grant, or to any benefit arising from it. However, this clause does not apply to this Grant to the extent that this Grant is made with a corporation for the corporation's general benefit.

24. Subawards and Contracts/Subcontracts

The applicable Federal cost principles for subawards and contracts/subcontracts under this Grant shall be those otherwise applicable to the type of organization receiving the subaward, contract or subcontract. In addition to OMB Circular A-21, the other applicable cost principles are:

(a) OMB Circular A-122, applicable to other nonprofit organizations, except those specifically exempted by the circular.

(b) Subpart 31.2 of the Federal Acquisition Regulation (48 CFR 31.2), applicable to commercial firms and those nonprofit organizations specifically exempted from the provisions of OMB Circular A-122.

(c) OMB Circular A-87 (34 CFR 255), for state and local governments.

(d) 45 CFR 74, Appendix E, for hospitals.

CEROS

AMENDMENT OF SOLI(ATION/MODIFICATION OF CONTR. .T

1. CONTRACT ID CODE	PAGE OF
	1

2. AMENDMENT/MODIFICATION NO.	3. EFFECTIVE DATE	4. REQUISITION/PURCHASE REQ. NO.	5. PROJECT NO. (If applic
SEE PAGE 2	95FEB15	N/A	N/A

6. ISSUED BY CODE N47092

Office of Naval Research
Resident Representative
565 S. Wilson Avenue
Pasadena, CA 91106-3212

7. ADMINISTERED BY (If other than Item 6) CODE N63374

SEE BLOCK 14 BELOW

8. NAME AND ADDRESS OF CONTRACTOR (No., street, county, State and ZIP Code)

High Technology Development Corporation (HDTC)
An agency of the State of Hawaii
Mililani Technology Park
300 Kahelu Avenue, Suite 35
Mililani, HI 96789

CODE | FACILITY CODE

(√) 9A. AMENDMENT OF SOLICITATION N

9B. DATED (SEE ITEM 11)

X 10A. MODIFICATION OF CONTRACT/OF NO. SEE PAGE 2

10B. DATED (SEE ITEM 13)

11. THIS ITEM ONLY APPLIES TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in Item 14. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not tended.

Offers must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation or as amended, by one of the following methods: (a) By completing Items 8 and 15, and returning ______ copies of the amendment; (b) By acknowledging receipt of this amendment on each copy of the c submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLE MENT TO BE RECEIVED AT THE PLACE DESIGNATED FOR THE RECEIPT OF OFFERS PRIOR TO THE HOUR AND DATE SPECIFIED MAY RES IN REJECTION OF YOUR OFFER. If by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegra letter, provided each telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

12. ACCOUNTING AND APPROPRIATION DATA (If required)

N/A

13. THIS ITEM APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS, IT MODIFIES THE CONTRACT/ORDER NO. AS DESCRIBED IN ITEM 14.

(√)	
	A. THIS CHANGE ORDER IS ISSUED PURSUANT TO: (Specify authority) THE CHANGES SET FORTH IN ITEM 14 ARE MADE IN THE CONTRACT ORDER NO. IN ITEM 10A.
X	B. THE ABOVE NUMBERED CONTRACT/ORDER IS MODIFIED TO REFLECT THE ADMINISTRATIVE CHANGES (such as changes in paying off appropriation date, etc.) SET FORTH IN ITEM 14, PURSUANT TO THE AUTHORITY OF FAR 43.103(b).
	C. THIS SUPPLEMENTAL AGREEMENT IS ENTERED INTO PURSUANT TO AUTHORITY OF:
	D. OTHER (Specify type of modification and authority)

E. IMPORTANT: Contractor [X] is not, ☐ is required to sign this document and return ______ copies to the issuing office.

14. DESCRIPTION OF AMENDMENT/MODIFICATION (Organized by UCF section headings, including solicitation/contract subject matter where feasible.)

The contract administration office for the grants listed on Page 2 has been changed:

From: Office of Naval Research
Resident Representative
565 S. Wilson Avenue
Pasadena, CA 91106-3212 Telephone: (818) 405-0876

To: ONR Regional Office-Seattle
1107 NE 45th St., Suite 350
Seattle, WA 98105-4631 Telephone: (206) 526-3168

RECEIVED
FEB 16 1995
Center of Excellence
For Research in Ocean Sciences

Except as provided herein, all terms and conditions of the document referenced in Item 9A or 10A, as heretofore changed, remains unchanged and in full force and effect.

15A. NAME AND TITLE OF SIGNER (Type or print)		16A. NAME AND TITLE OF CONTRACTING OFFICER (Type or print)	
		CARLENA C. LEUFROY	
15B. CONTRACTOR/OFFEROR	15C. DATE SIGNED	16B. UNITED STATES OF AMERICA	16C. DATE SIGNED
(Signature of person authorized to sign)		BY Carlena C. Leufroy (Signature of Contracting Officer)	FEB 11 1995

NSN 7540-01-152-8070
PREVIOUS EDITION

Agreement Number	Modification Number
MDA972-93-1-0008	A00001
MDA972-94-1-0010	A00001

ADVANCED RESEARCH PROJECTS AGENCY
3701 NORTH FAIRFAX DRIVE
ARLINGTON, VA 22203-1714

RECEIVED
FEB 16 1995
Center of Excellence
for Research in Ocean Sciences

Grant No.: MDA972-94-1-0010
ARPA Order No.: A217/02&03
Effective Date: 26 January 1995
Amendment: 0002

Grantor: Advanced Research Projects Agency
Contracts Management Office
3701 North Fairfax Drive
Arlington, VA 22203-1714
(Attn: John H. Ablard, 703/696-2383)

RECEIVED
FEB - 6 1995
HIGH TECHNOLOGY
DEVELOPMENT CORP.

Grantee: High Technology Development Corporation (HDTC)
An agency of the State of Hawaii
Mililani Technology Park
300 Kahelu Avenue, Suite 35
Mililani, HI 96789

Previous Total Grant Amount:	$5,000,000
Current Total Grant Amount:	$5,449,974
Total Grant Funding This Action:	$ 449,974

Accounting and Appropriation Data:

ACR:	AB 9740400.1320 A217 P4L10 2525 DPAC 4 5136 503733	$199,610
	AC 9750400.1320 A217 P5L10 2525 DPAC 4 5084 503733	$250,364

Authority: This Grant is modified pursuant to the authority of 10 U.S.C. 2358.

This Grant is modified as follows:

a. The Advanced Research Projects Agency is interested in furthering the development of Ocean Thermal Energy Conversion (OTEC) technology. CEROS will fund advanced research and development of the design, construction and operation of a 50kW closed cycle (CC) OTEC plant and conceptual design of a one megawatt CC-OTEC plant utilizing the design and operational experience of the 50 kW plant.

b. Revise the payment schedule as follows:

Payment Number	Amount	Payment Date
1	$400,000	Upon Grant Execution
2	$2,000,000	1 October 1994
2A	$249,974	1 February 1995
2B	$200,000	1 June 1995
3	$900,000	1 January 1995
4	$900,000	1 April 1995
5	$550,000	1 July 1995
6	$250,000	Upon Grant Completion

All provisions, terms, and conditions set forth in this Grant are applicable and in full force and effect except as specified herein.

FOR the United States of America,
the Advanced Research Projects Agency

By: ______________________
JOHN H. ABLARD
(Grants Officer)

1/27/95
(Date)

For: CEO, High Technology Development Corporation(HDTC)
The Trustees of the State of Hawaii

Accepted By: ______________________
(Grantee)

Executive Director & CEO
(Title)

February 13, 1995
(Date)

APPENDIX B
CEROS CHRONOLOGY OF SIGNIFICANT EVENTS

Note: this is the complete CEROS chronology through June 30, 1999. Items that pertain to the 94 Grant are highlighted in yellow. Items that are included in the appendices of this report are highlighted in green.

CEROS CHRONOLOGY

DATE	EVENT
11 JAN 93	HTDC presents proposed Operational Plan for CEROS to ARPA - Honolulu
22 FEB 93	ARPA Grant MDA972-93-1-0008 to HTDC for FY93 CEROS support
05 APR 93	W. Friedl reports aboard as CEROS Research Administrator
03 MAY 93	CEROS office established at Manoa Innovation Center
13 MAY 93	Broad Agency Announcement issued for FY93 Core Research Program
10 AUG 93	ARPA briefed on CEROS FY93 Core Research Program - Washington, DC
23 AUG 93	HTDC Board recommends starting contract negotiations for the 10 projects selected for FY93 Core Research Program
20 SEP 93	J. Smith reports aboard as CEROS Secretary
26-28 JAN 94	ARPA Review of CEROS Program - Honolulu
03 MAR 94	HTDC accepts operational responsibility for the Makai Research Pier and assigns managerial control to CEROS
29 MAR 94	[redacted]
02 MAY 94	J. Haun reports aboard as CEROS Director
04 MAY 94	ONR-sponsored Underwater Ordnance Survey Technology Workshop coordinated by CEROS at MRTC - Maui
25 MAY 94	[redacted]
25-26 JULY 94	Consortia for Competitiveness in Pursuit of Federal Funding Opportunities co-sponsored by CEROS - Honolulu
02 AUG 94	ARPA briefed on CEROS FY94 Core Research Program - Washington, DC
10 AUG 94	HTDC Board recommends starting contract negotiations for the 14 projects selected for FY94 Core Research Program
7-9 SEP 94	CEROS booth part of Hawaii Ocean R&D exhibit at Marine Technology Society annual meeting - Washington, DC
10-11 OCT 94	CEROS Director's Program Review of FY93 Core projects - Honolulu
02 NOV 94	CEROS File activated on DBEDT electronic bulletin board system
16 DEC 94	CEROS office relocated to Bishop Square, downtown Honolulu
19 DEC 94	[redacted]
26 JAN 95	ARPA provides additional CEROS funding for advanced R&D on closed cycle OTEC technology

DATE	EVENT
06 FEB 95	ARPA issues Funding Order for FY95 CEROS support
7-9 FEB 95	[redacted]
04 MAY 95	HTDC Board votes unanimously to effect and execute the transfer of CEROS to NELHA
24 MAY 95	ARPA briefed on CEROS FY95 Core Program - Washington, DC
02 JUNE 95	J. Haun completes Intergovernmental Personnel Assignment as CEROS Director to return to NRaD Laboratory, San Diego
09 JUNE 95	HTDC Board accepts plan to issue contracts for 8 projects selected for FY95 Core Program
18 JULY 95	NELHA Board approves plan to transfer CEROS to NELHA; Board declines to take over Makai Pier as part of transfer
01 AUG 95	DBEDT Director approves NELHA Board request to transfer CEROS according to NELHA plan
19 SEP 95	NELHA Board approves CEROS request to negotiate contracts for 4 additional projects for the FY95 Core program
05 OCT 95	HTDC Board votes to return control of Makai Pier to state Dept. of Land & Natural Resources (DLNR)
09-12 OCT 95	CEROS booth part of Hawaii Ocean R&D exhibit at MTS/IEEE OCEANS'95 meeting - San Diego, CA
16-18 OCT 95	[redacted]
05 DEC 95	NELHA Board selects W. Friedl for CEROS Director
21 DEC 95	[redacted]
02 JAN 96	CEROS grant administration is officially transferred to NELHA from HTDC by federal Grants Officer
06-07 FEB 96	[redacted]
20 MAY 96	DARPA briefed on CEROS FY96 Core Program - Washington, DC
21 MAY 96	NELHA Board approves CEROS request to negotiate and issue contracts for FY96 Core program
01 JUNE 96	J. Brewbaker begins as CEROS Administrative Assistant
15 JULY 96	CEROS Program Management Office moved to NELHA facility, Kailua-Kona
15 JULY 96	D. Mau reports aboard as CEROS Contracts & Grants Administrator
15 JULY 96	M. Mitchell reports aboard as CEROS Secretary
01 AUG 96	K. Dalrymple reports aboard as CEROS Accounts Clerk
23-26 SEP 96	CEROS booth part of Hawaii Ocean R&D exhibit at MTS/IEEE OCEANS'95 meeting - Ft. Lauderdale, FL
30-31 OCT 96	[redacted]

DATE	EVENT
01 NOV 96	U. S. Senator Daniel K. Inouye dedicates the CEROS offices at NELHA facility in Kailua-Kona
11 DEC 96	Broad Agency Announcement issued for FY97 Core program
5-6 FEB 97	[redacted]
20 MAY 97	NELHA Board approves CEROS request to negotiate and issue contracts for FY97 Core program
05 JUNE 97	DARPA briefed on CEROS FY97 Core Program - Washington, DC
30 JUNE 97	M. Mitchell successfully completes assignment as CEROS Secretary
30 JUNE 97	K. Dalrymple successfully completes assignment as CEROS Accounts Clerk
01 JULY 97	J. Brewbaker begins as CEROS Program Manager for Outreach & Administration
08 JULY 97	C. Giles reports aboard as CEROS Office Manager
06-09 OCT 97	CEROS booth part of Hawaii Ocean R&D exhibit at MTS/IEEE OCEANS'97 meeting - Halifax, Nova Scotia, Canada
10 OCT 97	Broad Agency Announcement issued for FY98 Core program
28-29 OCT 97	CEROS Program Review of FY97 Core Projects - Honolulu
30 OCT 97	CEROS Informational Meeting - Honolulu
10 NOV 97	L. Muehlhausen reports aboard as CEROS Program Manager for Technology Development & Transfer
4-6 FEB 98	DARPA Site Visit and Program Review, Honolulu
19 FEB 98	NELHA Board approves CEROS request to negotiate and issue contracts for FY98 Core program
06 MAR 98	DARPA briefed on CEROS FY98 Core Program - Washington, DC
20 MAY 98	CEROS/SBIR Meeting – NELHA, Kailua-Kona
14-15 JULY 98	DARPA Review of CEROS FY97 Core Projects – Honolulu
16 JULY 98	CEROS Informational Meeting and Hawaii Ocean Technology Exhibit – Ilikai Hotel, Honolulu
02 OCT 98	Broad Agency Announcement issued for FY99 Core program
27 OCT 98	CEROS FY99 Information Meeting – PMRF, Kauai
30 OCT 98	CEROS FY99 Information Meeting – MHPCC, Maui
12 NOV 99	CEROS Informational Video produced
16-19 NOV 98	CEROS booth part of Hawaii Ocean R&D exhibit at MTS Oceans Community Conference 98 meeting - Baltimore, MD
9 DEC 98	CEROS Contracts Office relocates to Grosvenor Center, downtown Honolulu

1-4 FEB 99	DARPA Site Visit and Program Review - Big Island and O'ahu

DATE	EVENT
16 FEB 99	NELHA Board approves CEROS request to negotiate and issue contracts for FY99 Core program
17 MAR 99	DARPA briefed on CEROS FY99 Core Program - Washington, DC
12 MAY 99	CEROS Proposal Writing Workshop - Ilikai Hotel, Honolulu
03 JUNE 99	CEROS Informational Meeting and Hawaii Ocean Technology Exhibit – Ilikai Hotel, Honolulu
30 JUNE 99	DARPA Grant MDA972-94-1-0010 expires. CEROS Core projects for FY94-FY96 completed.

LAN: CEROS PR \ Chronology – Revised March 1999

DARPA GRANT NO. MDA 972-94-1-0010
FINAL TECHNICAL REPORT

APPENDIX C
BROAD AGENCY ANNOUNCEMENTS

FY94 8 March 1994

FY95 19 December 1994

FY96 21 December 1995

CEROS BROAD AGENCY ANNOUNCEMENT

DATE: 8 March 1994

National Defense Center of Excellence for Research in Ocean Sciences (CEROS)
2800 Woodlawn Drive, Suite 243,
Honolulu, Hawaii 96822

A--OCEAN TECHNOLOGIES FOR INTEGRATED NAVY-MARINE FORCES.
SOL. BAA-CEROS-94-01

POC William A. Friedl, CEROS Management Office, Phone (808)539-3788.

BROAD AGENCY ANNOUNCEMENT (BAA-CEROS-94-01): (Ocean Technology Development in support of Integrated Navy-Marine Forces including but not limited to Shallow Water Surveillance Technologies, Ocean Environmental Preservation, New Ocean Platform and Ship Concepts, Ocean Measurement Instrumentation, and Unique Properties of the Deep Ocean Environment) SOL BAA-CEROS-94-01 DUE 15 APRIL 1994 POC William A. Friedl, (808) 539-3788. The National Defense Center of Excellence for Research in Ocean Sciences (CEROS) is soliciting proposals for concept exploration, analysis, study and development of ocean technologies and applied ocean science. Of particular interest are proposals for research, development and demonstration of advanced technologies for Shallow Water Surveillance, Ocean Environmental Preservation, New Ocean Platform and Ship Concepts, Ocean Measurement Instrumentation, and Unique Properties of the Deep Ocean Environment. Innovative concepts and new approaches are being sought to advance technology while fully leveraging existing facilities and infrastructure in Hawaii.

CEROS anticipates that initial contractor selections will be made during June 1994. Proposed work should be structured to have a base period of performance of 6 to 12 months. Options to extend the period of performance beyond 12 months may be included in proposals.

Subject areas of interest include:

(1) Shallow Water Surveillance Technologies, including: Low cost sensors and hydrophones, advanced signal processing for detection and tracking of surface ships and submarines, shallow water anti-submarine warfare, mine countermeasures, and ship defense.

(2) Ocean Environmental Preservation, including: *In situ* contaminants and properties measurements, spectral remote sensing, monitoring of the effects of acoustic emissions on marine mammal behavior, environmental information data base development to support environmental preservation in the ocean, non-point source pollution, acute biotoxicity and bioaccumulation, explosive ordnance and waste disposal, and environmental cleanup or remediation.

(3) New Ocean Platform and Ship Concepts, including: Unique structures, simulation-based design and model development, affordability, connector and joining technologies, assembly and manufacturing technology, offshore platforms or bases, and new hull designs.

(4) Ocean Measurement Instrumentation, including: Nondestructive testing systems, low power, autonomous data collection platforms, advanced geophysical survey technologies, advanced sensors, and laser technology, and modeling, measurements and predictions.

(5) Unique Properties of the Deep Ocean Environment, including: Deep seawater chemistry and biology, deep seawater materials testing, and energy and fuel production potentials.

Offerors responding to this BAA shall submit an unclassified Abstract of the proposed effort to CEROS by 3 PM, 15 April 1994. The abstract should provide an overview of the project and associated costs and shall be prepared on 8.5 x 11 inch plain paper printed on one side only in the following format: single or double spaced, in at least ten point type, with margins not less than one inch, and pages numbered. An original Abstract and six copies are requested for each submission. Each Abstract should be unbound with the pages secured by a single staple in the upper left hand corner.

Each Abstract shall address one subject area and must be no longer than 5 single-sided pages. Abstracts longer than 5 pages will be deemed unresponsive. The total page count includes figures and tables. The Abstract shall consist of a cover page and up to 4 additional pages of proposal information. The Cover Page shall include the following: Title of the proposed effort, Technical subject area addressed, Intended product or result, Name and affiliation of the Principal Investigator and administative point of contact, Proposed period of performance, Funding required to produce the proposed products, Names of sub-contractors and co-investigators, and Special requirements or considerations . The balance of the Abstract shall include the following sections, each clearly labeled:

A. Rationale for the proposed effort, stressing (a) the work's relationship to Department of Defense (DoD) technological needs and (b) value added aspects of the work for DoD, CEROS, and the State of Hawaii.

B. Technical Objectives of the work, emphasizing the innovation and leading edge aspects of the research or technology development.

C. Technical Approach, describing how the work will be executed and giving an outline of the planned work schedule and significant milestones.

D. Expected Results or Products, discussing what the proposed effort will produce, how the results will be demonstrated and why those deliverables will advance ocean science or technology, address DoD needs and bring added value to Hawaii or the Central Pacific.

The Abstract may also contain any other information germane to the proposed effort, such as discussions of leveraged assets involved, technology reinvestment or transfer aspects of the proposed work, company qualifications or technical references.

EVALUATION CRITERIA

Proposals will be evaluated competitively. Depending on results from evaluations of Abstracts, CEROS will request more detailed technical and cost proposals from some offerors before selecting projects for award. The following criteria apply to both Abstracts and longer proposals requested under this announcement. CEROS will select for award those proposals offering the best value and, except for the first criterion (item A), will give equal consideration to each of the following criteria. Item A will receive twice the weight of any other criterion in the evaluation.

A. Scientific/technical quality of the research proposal and its relevance to the topic description, with special emphasis on its innovation and originality.

B. Qualifications of the principal investigator, other key staff, and consultants (if any) and the adequacy of instruments and facilities involved, considering the potential for the effort to use and levrage equipment, facilities or infrastructure in Hawaii .

C. Anticipated benefits of the research, its potential value to the Department of Defense and potential for stimulating ocean technology business development in Hawaii.

D. Defensibility of estimated costs.

CEROS plans to make up to $5M available to fund proposals in response to this announcement. Out-year funding has not been defined. Multiple, fixed price or cost plus fixed fee contracts are anticipated to be awarded as a result of this BAA. Contract awards will be based on proposal merit and funding availability. CEROS anticipates that initial selections will be made during June 1994.

(1) It is CEROS policy to treat all proposals as competitive information and to disclose the contents only for the purposes of evaluation. CEROS may use selected support contractors as special resources to evaluate abstracts and proposals. These contractors are restricted by their contracts from disclosing the proposal information or using it for purposes other than the technical assessments. CEROS evaluators are required to sign non-disclosure statements. By submitting an abstract of your proposal, you agree that the technical and management information may be disclosed to those selected contractors for the limited purpose stated above. Any information submitted with your proposal that you do not consent to limited release to these contractors must be clearly marked and submitted segregated from other proposal material.

(2) All abstracts submitted under this BAA must be unclassified. If offerors propose to undertake classified work or require access to classified information, they must be able to certify that they have a Secret facility clearance, and key personnel must be certified as holding a Secret clearance. Abstracts must clearly state that the proposed work will be classified.

(3) CEROS is planning a one-day meeting to provide information and answer questions about this BAA. The meeting will be held in Honolulu, HI on 21 March 1994. Information from the meeting will also be available to potential offerors upon request. Contact the CEROS Management Office to register for the meeting or request information.

(4) Contact Point: questions relating to this BAA are to be directed to attn: Mr. William A. Friedl, CEROS Management Office, 2800 Woodlawn Drive, Suite 243, Honolulu, Hawaii 96822, (808) 539-3788.

All responsive sources may submit a proposal abstract, which shall be considered by CEROS. CEROS reserves the right to select for award all, some, or none of the proposals received in response to this announcement.

CEROS BROAD AGENCY ANNOUNCEMENT

FY95 CEROS BROAD AGENCY ANNOUNCEMENT

DATE: 19 December 1994

National Defense Center of Excellence for Research in Ocean Sciences
(CEROS)
1001 Bishop Street
Pacific Tower Suite 2490
Honolulu, Hawaii 96813

A--OCEAN TECHNOLOGIES FOR INTEGRATED NAVY-MARINE FORCES.
SOL. BAA-CEROS-95-01

POC William A. Friedl, CEROS Project Office, Phone (808)587-5500.

BROAD AGENCY ANNOUNCEMENT (BAA-CEROS-95-01): (Ocean Technology Development in support of Integrated Navy-Marine Forces including but not limited to Shallow Water Surveillance Technologies, Ocean Environmental Preservation, New Ocean Platform and Ship Concepts, Ocean Measurement Instrumentation and Ocean Engineering Tools, and Unique Properties of the Deep Ocean Environment) SOL BAA-CEROS-95-01 DUE 18 September 1995 POC William A. Friedl, (808) 587-5500.

The National Defense Center of Excellence for Research in Ocean Sciences (CEROS) is soliciting proposals for concept exploration, analysis, study and development of ocean technologies and applied ocean science. Of particular interest are proposals for research, development and demonstration of advanced technologies for Shallow Water Surveillance, Ocean Environmental Preservation, New Ocean Platform and Ship Concepts, Ocean Measurement Instrumentation and Ocean Engineering Tools, and Unique Properties of the Deep Ocean Environment. Innovative concepts and new approaches are being sought to advance technology while fully leveraging existing facilities and infrastructure in Hawaii and demonstrating beneficial commercial utility for Department of Defense applications.

Contract awards will be based on proposal merit and funding availability. CEROS anticipates that initial contractor selections will be made during May 1995. However, properly formatted proposal abstracts submitted within nine months after publication of this BAA will be considered for award if funding is available. Proposed work should be structured to have a base period of performance of 6 to 12 months. Options to extend the period of performance beyond 12 months may be included in proposals. CEROS will use a two-step submission process in the evaluation of proposals submitted under this BAA. For the first submission step, offerors are required to submit a Proposal Abstract to be considered. CEROS will evaluate all abstracts against the evaluation criteria

herein without regard to other abstracts submitted. For the second step, CEROS will request full technical and cost proposals from selected offerors for proposed efforts deemed as best qualified for potential negotiation under this BAA. Proposal format and length for full proposals will be specified by CEROS in the invitation to submit the more detailed proposal. Such an invitation does not assure subsequent award. The decision to submit or not submit a full proposal is the responsibility of
the offeror submitting the abstract. No selections for negotiation will be made under this BAA without a full technical and cost proposal.

Subject areas of interest include:

(1) Shallow Water Surveillance Technologies, including: Low cost sensors and hydrophones, advanced signal processing for detection and tracking of surface ships and submarines, shallow water anti-submarine warfare, mine countermeasures, and ship defense.

(2) Ocean Environmental Preservation, including: *In situ* contaminants and properties measurements, spectral remote sensing, microelectronic and/or micromechanical systems development to provide real-time, *in situ* data on environmental parameters, environmental information data base development to support environmental preservation in the ocean, non-point source pollution, acute biotoxicity and bioaccumulation, explosive ordnance and waste disposal, and environmental cleanup or remediation.

(3) New Ocean Platform and Ship Concepts, including: Unique structures, simulation-based design and model development, affordability, connector and joining technologies, assembly and manufacturing technology, offshore platforms or bases, and new hull designs.

(4) Ocean Measurement Instrumentation and Ocean Engineering Tools, including: Advanced sensors, subsystems and/or components for teleoperated structures (TOS), nondestructive testing systems, low power autonomous data collection platforms, advanced geophysical survey technologies, laser applications, and modeling, measurements and predictions.

(5) Unique Properties of the Deep Ocean Environment, including: Deep seawater chemistry and biology, deep seawater materials testing, and energy and fuel production potentials.

To be considered in the initial contract award period, offerors responding to this BAA shall submit an unclassified Abstract of the proposed effort to CEROS by 3 PM, Hawaii Standard Time, 3 February 1995. The abstract should provide an overview of the project and associated costs and shall be prepared on 8.5 x 11 inch plain paper printed on one side only in the following format: single or double spaced, in at least ten point type, with margins not less than one inch, and pages numbered. An original Abstract and six copies are requested for each submission. Each Abstract should be unbound with the pages secured by a single staple in the upper left hand corner. Abstracts or full proposals may not be submitted by telefax or electronic mail, any so sent will be rejected. Acknowledgment of receipt of abstracts or proposals will not be made, and

abstracts or proposals will not be returned. CEROS will attempt to respond to all Abstracts received in the initial_contract award period by 9 March 1995.

Each Abstract shall address one subject area and must be no longer than 5 single-sided pages. Abstracts longer than 5 pages will be deemed unresponsive. The total page count includes figures and tables. The Abstract shall consist of a cover

page and up to 4 additional pages of proposal information. The Cover Page shall include the following:
Title of the proposed effort, Technical subject area addressed, Intended product or result, Name and affiliation of the Principal Investigator and administrative point of contact, Proposed period of performance, Funding required to produce the proposed products, Names of sub-contractors and co-investigators, and Special requirements or considerations . The balance of the Abstract shall include the following sections, each clearly labeled:

A. Rationale for the proposed effort, stressing (a) the work's relationship to Department of Defense (DoD) technological needs and (b) value added aspects of the work for DoD, CEROS, and the State of Hawaii.

B. Technical Objectives of the work, emphasizing the innovation and leading edge aspects of the research or technology development.

C. Technical Approach, describing how the work will be executed and giving an outline of the planned work schedule and significant milestones.

D. Expected Results or Products, discussing what the proposed effort will produce, how the results will be demonstrated and why those deliverables will advance ocean science or technology, address DoD needs and bring added value to Hawaii or the Central Pacific.

The Abstract may also contain any other information germane to the proposed effort, such as discussions of leveraged assets involved, technology reinvestment or transfer aspects of the proposed work, company qualifications or technical references.

EVALUATION CRITERIA

The following criteria apply to both Abstracts and full proposals requested under this announcement. CEROS will select for award those proposals offering the best value and, except for the first criterion (item A), will give equal consideration to each of the following criteria. Item A will receive twice the weight of any other criterion in the evaluation.

A. Scientific/technical quality of the research proposal and its relevance to the topic description, with special emphasis on its innovation and originality.

B. Qualifications of the principal investigator, other key staff, and consultants (if any) and the adequacy of instruments and facilities involved, considering the potential for the effort to use and leverage equipment, facilities or infrastructure in Hawaii .

C. Anticipated benefits of the research, its potential value to the Department of Defense and potential for stimulating ocean technology business development in Hawaii.

D. Overall cost and realism of cost for proposed effort.

CEROS plans to make up to $7M available to fund proposals in response to this announcement. Out-year funding has not been defined. Multiple, fixed price or cost plus fixed fee contracts, not exceeding $1M each, are anticipated to be awarded as a result of this BAA. Contract awards will be based on proposal merit and funding availability. CEROS anticipates that initial selections for awards will be made in May 1995. CEROS may request that successful offerors deliver two presentations on their research to Hawaii high school students.

(1) This solicitation will remain open for nine months (274 days) from the date of this announcement. However, to be considered in the initial award period, a properly formatted abstract must be received by CEROS by 3 PM, Hawaii Standard Time, 3 February 1995.

(2) It is CEROS policy to treat all proposals as competitive information and to disclose the contents only for the purposes of evaluation. CEROS may use selected support contractors as special resources to evaluate abstracts and proposals. These contractors are restricted by their contracts from disclosing the proposal information or using it for purposes other than the technical assessments. CEROS evaluators are required to sign non-disclosure statements. By submitting an abstract of your proposal, you agree that the technical and management information may be disclosed to those selected contractors for the limited purpose stated above. Any information submitted with your proposal that you do not consent to limited release to these contractors must be clearly marked and submitted segregated from other proposal material.

(3) All abstracts submitted under this BAA must be unclassified. If offerors propose to undertake classified work or require access to classified information, they must be able to certify that they have a Secret facility clearance, and key personnel must be certified as holding a Secret clearance. Abstracts must clearly state that the proposed work will be classified.

(4) Information about CEROS and Hawaii Ocean R&D is available to potential offerors upon request from the CEROS Project Office.

(5) Contact Point: questions relating to this BAA are to be directed to attn.: Mr. William A. Friedl, CEROS Project Office,1001 Bishop Street, Pacific Tower Suite 2490, Honolulu, Hawaii 96813, phone (808) 587-5500.

All responsive sources may submit a proposal abstract, which shall be considered by CEROS. CEROS reserves the right to select for award all, some, or none of the proposals received in response to this announcement.

CEROS BROAD AGENCY ANNOUNCEMENT

DATE: 21 December 1995

National Defense Center of Excellence for Research in Ocean Sciences
(CEROS)
1001 Bishop Street
Pacific Tower Suite 2490
Honolulu, Hawaii 96813

A--OCEAN TECHNOLOGIES FOR INTEGRATED NAVY-MARINE FORCES.
SOL. BAA-CEROS-96-01

POC William A. Friedl, CEROS Project Office, Phone (808)587-5500.

BROAD AGENCY ANNOUNCEMENT (BAA-CEROS-95-01): (Ocean Technology Development in support of Integrated Navy-Marine Forces including but not limited to Shallow Water Surveillance Technologies, Ocean Environmental Preservation, New Ocean Platform and Ship Concepts, Ocean Measurement Instrumentation and Ocean Engineering Tools, and Unique Properties of the Deep Ocean Environment) SOL BAA-CEROS-96-01 DUE 30 August 1996 POC William A. Friedl, (808) 587-5500.

The National Defense Center of Excellence for Research in Ocean Sciences (CEROS) is soliciting proposals for concept exploration, analysis, study and development of ocean technologies and applied ocean science. Of particular interest are proposals for research, development and demonstration of advanced technologies for Shallow Water Surveillance, Ocean Environmental Preservation, New Ocean Platform and Ship Concepts, Ocean Measurement Instrumentation and Ocean Engineering Tools, and Unique Properties of the Deep Ocean Environment. Innovative concepts and new approaches are being sought to advance technology while fully leveraging existing facilities and infrastructure in Hawaii and demonstrating beneficial commercial and/or military utility for Department of Defense applications. CEROS anticipates executing the program outlined in this announcement contingent upon funding amount and availability.

Contract awards will be based on proposal merit and funding availability. CEROS anticipates that initial contractor selections will be made during May 1996. However, properly formatted proposal abstracts submitted before 30 August 1996 will be considered for award if funding is available. Proposed work should be structured to have a base period of performance of 6 to 12 months. Options to extend the period of performance beyond 12 months may be included in proposals. CEROS will use a two-step submission process in the evaluation of proposals submitted under this BAA. For the first submission step, offerors are required to submit a Proposal Abstract to be considered. CEROS will evaluate

all abstracts against the evaluation criteria herein without regard to other abstracts submitted. For the second step, CEROS will request full technical and cost proposals from selected offerors for proposed efforts deemed as best qualified for potential negotiation under this BAA. Proposal format and length for full proposals will be specified by CEROS in the invitation to submit the more detailed proposal. Such an invitation does not assure subsequent award. The decision to submit or not submit a full proposal is the responsibility of the offeror submitting the abstract. No selection for negotiation will be made under this BAA without a full technical and cost proposal.

Subject areas of interest include:

(1) Shallow Water Surveillance Technologies, including: Low-cost sensors and hydrophones, Unique array configurations, Neural network applications, Advanced signal processing techniques, Shallow water ASW, Mine countermeasures, and Ship defense.

(2) Ocean Environmental Preservation, including: *In Situ* measurements, Spectral remote sensing technologies, Microelectronic and/or micromechanical systems development , Non-point source pollution measurement and remediation, Explosive ordnance disposal, and Environmental cleanup or remediation technologies.

(3) New Ocean Platform and Ship Concepts, including: Unique structures, Simulation based design and model development, Affordability, Automation, Assembly and Manufacturing technology, and New hull designs.

(4) Ocean Measurement Instrumentation and Ocean Engineering Tools, including: Advanced sensors and geophysical survey technologies, Subsystems or components for teleoperated structures (TOS) , Nondestructive testing systems, Low power, autonomous data collection platforms and technologies, Laser applications, and Modeling, measurements and predictions.

(5) Unique Properties of the Deep Ocean Environment, including: Deep seawater chemistry and biology, deep seawater materials testing, and energy and fuel production potentials.

To be considered in the initial contract award period, offerors responding to this BAA shall submit an unclassified Abstract of the proposed effort to CEROS by 3 PM, Hawaii Standard Time, 9 February 1996. The abstract should provide an overview of the project and associated costs and shall be prepared on 8.5 x 11 inch plain paper printed on one side only in the following format: single or double spaced, in at least ten point type, with margins not less than one inch, and pages numbered. An original Abstract and six copies are requested for each submission. Each Abstract should be unbound with the pages secured by a single staple in the upper left hand corner. Abstracts or full proposals may not be submitted by telefax or electronic mail, any so sent will be rejected. Acknowledgment of receipt of abstracts or proposals will not be made, and abstracts or proposals will not be returned. CEROS will attempt to respond to all Abstracts received in the initial contract award period by 20 March 1996.

Each Abstract shall address one subject area and must be no longer than 5 single-sided pages. Abstracts longer than 5 pages will be deemed unresponsive. The total page count includes figures and tables. The Abstract shall consist of a cover
page and up to 4 additional pages of proposal information. The Cover Page shall include the following:
Title of the proposed effort, Technical subject area addressed, Intended product or result, Name and affiliation of the Principal Investigator and administrative Point of Contact, Proposed period of performance, Funding required to produce the proposed products, Names of sub-contractors and co-investigators, and Special requirements or considerations . The balance of the Abstract shall include the following sections, each clearly labeled:

A. Rationale for the proposed effort, stressing (a) the work's relationship to Department of Defense (DoD) technological needs and (b) value added aspects of the work for DoD, CEROS, and the State of Hawaii.

B. Technical Objectives of the work, emphasizing the innovation and leading edge aspects of the research or technology development.

C. Technical Approach, describing how the work will be executed and giving an outline of the planned work schedule and significant milestones.

D. Expected Results or Products, discussing what the proposed effort will produce, how the results will be demonstrated and why those deliverables will advance ocean science or technology, address DoD needs and bring added value to Hawaii or the Central Pacific.

The Abstract may also contain any other information germane to the proposed effort, such as discussions of leveraged assets involved, technology reinvestment or transfer aspects of the proposed work, company qualifications or technical references.

EVALUATION CRITERIA

The following criteria apply to both Abstracts and full proposals requested under this announcement. CEROS will select for award those proposals offering the best value and, except for the first criterion (item A), will give equal consideration to each of the following criteria. Item A will receive twice the weight of any other criterion in the evaluation.

A. Scientific/technical quality of the research proposal and its relevance to the topic description, with special emphasis on its innovation and originality.

B. Qualifications of the principal investigator, other key staff, and consultants (if any) and the adequacy of instruments and facilities involved, considering the potential for the effort to use and leverage equipment, facilities or infrastructure in Hawaii .

C. Anticipated benefits of the research, its potential value to the Department of Defense and potential for stimulating ocean technology business development in Hawaii.

D. Overall cost and realism of cost for proposed effort.

CEROS BROAD AGENCY ANNOUNCEMENT

CEROS plans to make up to $7M available to fund proposals in response to this announcement, depending on funding availability. Out-year funding has not been defined. Multiple, fixed price or cost plus fixed fee contracts, not exceeding $1M each, are anticipated to be awarded as a result of this BAA. Contract awards will be based on proposal merit and funding availability. CEROS anticipates that initial selections for awards will be made in May 1996. CEROS may request that successful offerors deliver two presentations on their research to Hawaii high school students.

(1) This solicitation will remain open for eight months (254 days) from the date of this announcement. However, to be considered in the initial award period, a properly formatted abstract must be received by CEROS by 3 PM, Hawaii Standard Time, 9 February 1996.

(2) It is CEROS policy to treat all proposals as competitive information and to disclose the contents only for the purposes of evaluation. CEROS may use selected support contractors as special resources to evaluate abstracts and proposals. These contractors are restricted by their contracts from disclosing the proposal information or using it for purposes other than the technical assessments. CEROS evaluators are required to sign non-disclosure statements. By submitting an abstract of your proposal, you agree that the technical and management information may be disclosed to those selected contractors for the limited purpose stated above. Any information submitted with your proposal that you do not consent to limited release to these contractors must be clearly marked and submitted segregated from other proposal material.

(3) All abstracts submitted under this BAA must be unclassified. If offerors propose to undertake classified work or require access to classified information, they must be able to certify that they have a Secret facility clearance, and key personnel must be certified as holding a Secret clearance. Abstracts must clearly state that the proposed work will be classified.

(4) Information about CEROS and Hawaii Ocean R&D is available to potential offerors upon request from the CEROS Project Office or through the CEROS website at http://www.ceros.org/.

(5) Contact Point: questions relating to this BAA are to be directed to attn.: Mr. William A. Friedl, CEROS Project Office,1001 Bishop Street, Pacific Tower Suite 2490, Honolulu, Hawaii 96813, phone (808) 587-5500.

All responsive sources may submit a proposal abstract, which shall be considered by CEROS. CEROS reserves the right to select for award all, some, or none of the proposals received in response to this announcement. The program described in this announcement is contingent upon funding availability.

APPENDIX D
CEROS PROGRAM REVIEWS

FY94	**February 7-9, 1995**
FY94	**October 16-18, 1995**
FY95	**February 7-8, 1996**
FY95	**October 30-31, 1996**
FY96	**February 5-6, 1997**

ARPA PROGRAM REVIEW OF CEROS FY94 PROJECTS
7-9 FEB 95
CEROS MANAGEMENT OFFICE, HONOLULU

TUESDAY, 7 February

TIME	PRESENTATION / EVENT
1300	**Innovations Hawaii** *Extended Source Apparent Motion (E-SAM) Lighted Signals for Protection of the Marine Environment*
1400	**Gateway Technologies International, Inc.** *HIRADSIM Workstation Development Project - Continuation of Existing Work Advanced HIRADSIM Small Target - Time Domain - Maritime Radar Model*
1500	**Knapp Engineering, Inc. & OCEANIT Laboratories, Inc.** *Low-Cost Prebuckled Cylindrical Pressure Hulls*
1600	**Sea Engineering, Inc.** *Development of a Technique to Identify Pollutant Sources and Impacts in Coastal and Oceanic Waters*
1700	PAU

WEDNESDAY, 8 February

TIME	PRESENTATION / EVENT
0730	EXECUTIVE SESSION
0800	**Alliant Techsystems** *High-Resolution Bottom-Penetrating Acoustic Sensors and Signal Processing Algorithms for Reduction of False-Alarm Probability in UXO Hunting*
0900	**ORINCON Hawaii, Incorporated** *Underwater Echolocation for Object Recognition*
1000	**Pacific Marine & Supply Company, Inc.** *Tri-Strut Ship Research and Development*
1100	**Ocean Engineering Consultants, Inc.** *SWATH Motion/Structural Software Development*
1200	LUNCH (BROUGHT IN)
1300	**Sea Engineering, Inc.** *Development of a Broadband FM Sub-Bottom Profiler for Seafloor Imaging and Sediment Classification*
1400	**Makai Ocean Engineering, Inc.** *Development of an Automated Control System for Deployment of Small Diameter Cables and Towed Bodies*
1500	**SETS Technology, Inc.** *Hyperspectral Remote Sensing for Maritime Applications: Phase II*
1600	EXECUTIVE SUMMARY
1630	PAU

ARPA PROGRAM REVIEW OF CEROS FY94 PROJECTS
7-9 FEB 95
CEROS MANAGEMENT OFFICE, HONOLULU

THURSDAY, 9 February

TIME	PRESENTATION / EVENT
1300	**Makai Ocean Engineering, Inc.** *Development of a Cost-Effective GPS-Based Sensor for Measurement of Heave, Pitch, Roll and Heading on Oceanographic Platforms (Phase II)*
1400	**Aquaculture Technology Incorporated** *Naturally Occurring Antibodies from Marine Algae Chaetoceros*
1500	**Detection Limit Technology, Inc.** *Development of a Fiber-Optic Based Autonomous Buoy for In-Situ Monitoring of pH, pCO_2, Temperature, O_2, and Water Quality in Seawater*
1600	EXECUTIVE SUMMARY
1630	PAU

The following notes have been sent to each project's Principal Investigator:

⇒ Presentations will be made in the CEROS Project Office Conference Room.

⇒ Each presentation will begin on the hour and end 50 minutes past the hour.

⇒ Each presentation will include up to 25 minutes of technical overview followed by up to 25 minutes of Q&A/discussion.

⇒ The technical overview will include the FY94 project objectives, expected products/results and budget and will specify the project's principal technical risks, innovation, and schedule.

⇒ Each presentation team will be limited to 3 people, maximum. The project PI will be responsible for the presentation.

PROGRAM REVIEW

CEROS PROJECT OFFICE - 1001 Bishop Street Suite 2490

Contractor Presentations on Plans for 1994 CEROS Core Research Program

Reviewers:

Dr. William M. Carey (703)696-2339	Program Manager ARPA Maritime Systems Technology Office
Mr. Jeff Haun (808) 587-5500	Director CEROS
Dr. Theo Kooij (703) 696-2333	Program Manager ARPA Maritime Systems Technology Office
CAPT R. J. LaDouce (808) 471-0363	Commanding Officer Navy Pacific Meteorology and Oceanography Center
Dr. Craig MacDonald (808) 587-2690	Branch Chief, Ocean Resources Branch Dept. Business, Economic Development & Tourism
Ms. Celia Metz (619) 553-3665	Program Manager, Adaptive Systems Branch NCCOSC RDT&E Division (NRaD), San Diego, CA
Dr. Antares Parvulescu (703) 768-8706	Senior Scientist Naval Research Laboratory, Washington, DC
Dr. Paul Rispin (703) 696-8105	Technical Manager, Environmental Quality Division Office of Naval Research
Dr. J. Richard Seesholtz (703) 516-6026	Senior Professional Staff The Johns Hopkins University Applied Physics Lab
Ms. Barbara Kim Stanton (808) 625-5293	Executive Director High Technology Development Corporation
Mr. Charles Stuart (703) 696-2315	Director ARPA Maritime Systems Technology Office
Dr. Ace Summey (904) 234-4472	Head of Dual Use Technologies Naval Coastal Systems Station, Panama City, FL
Dr. David Yun (808) 956-7627	Director, Information Technology Division Dept. of Electrical Engineering, University of Hawaii

Note: Individual reviewer attendance may vary for different presentations.

CEROS Point of Contact:

Bill Friedl, Research Administrator, (808) 587-5500.

MONDAY, 16 October

0830: Executive Session - Introduction

0930: *Extended Source Apparent Motion (E-SAM) Lighted Signals for Protection of the Marine Environment*
Innovations Hawaii (Honolulu, HI)

1030: *Low-Cost Prebuckled Cylindrical Pressure Hulls*
Knapp Engineering, Inc. (Aiea, HI)
OCEANIT Laboratories, Inc. (Honolulu, HI)

1130: Lunch

1300: *Naturally Occurring Antibodies from Marine Algae Chaetoceros*
Aquaculture Technology Incorporated (Honolulu, HI)

1400: *Development of a Technique to Identify Pollutant Sources and Impacts in Coastal and Oceanic Waters*
Sea Engineering, Inc. (Waimanalo, HI)

1500: *SWATH Motion/Structural Software Development*
Ocean Engineering Consultants, Inc. (Honolulu, HI)

1600: Pau

TUESDAY, 17 October

0830: *High-Resolution Bottom-Penetrating Acoustic Sensors and Signal Processing Algorithms for Reduction of False-Alarm Probability in UXO Hunting*
Alliant Techsystems (Mukilteo, WA)

0930: *Underwater Echolocation for Object Recognition*
ORINCON Hawaii, Incorporated (Kailua, HI)

1030: *Tri-Strut Ship Research and Development*
Pacific Marine & Supply Company, Inc. (Honolulu, HI)

1130: Lunch

1230: *Development of a Broadband FM Sub-Bottom Profiler for Seafloor Imaging and Sediment Classification*
Sea Engineering, Inc. (Waimanalo, HI)

1330: *HIRADSIM Workstation Development Project - Continuation of Existing Work Advanced HIRADSIM Small Target - Time Domain - Maritime Radar Model*
Gateway Technologies International, Inc. (Honolulu, HI)

1430: *Hyperspectral Remote Sensing for Maritime Applications: Phase II*
SETS Technology, Inc. (Mililani, HI)

1530: *Development of a Fiber-Optic Based Autonomous Buoy for In-Situ Monitoring of pH, pCO_2, Temperature, O_2, and Water Quality in Seawater*
Detection Limit Technology, Inc. (Waimanalo, HI)

1630: Pau

WEDNESDAY, 18 October

0800: *Development of an Automated Control System for Deployment of Small Diameter Cables and Towed Bodies*
Makai Ocean Engineering, Inc. (Kailua, HI)

0900: *Development of a Cost-Effective GPS-Based Sensor for Measurement of Heave, Pitch, Roll and Heading on Oceanographic Platforms (Phase II)*
Makai Ocean Engineering, Inc. (Kailua, HI)

1000: *Design, Construction, and Operation of a 50 kW Closed Cycle OTEC Plant and Applicationof Results to the Design of a One Megawatt OTEC Plant*
Makai Ocean Engineering, Inc. (Kailua, HI)

1100: Executive Session - Wrap-Up

1200: Pau

Notes:

⇒ Presentations will be made in the Conference Room at the CEROS Office.

⇒ Each presentation will begin either on the half-hour or the hour, as appropriate, and end 50 minutes later.

⇒ Each presentation will include up to 25 minutes of technical overview followed by up to 25 minutes of Q&A/discussion.

⇒ The technical overview will include the FY94 project **Objectives**, **Expected Products** or **Results**, and **Budget** and will specify the project's **Principal Technical Risks**, **Innovation**, and **Schedule.**

⇒ Each presentation team will be limited to 3 people, maximum. The project's Principal Investigator will be responsible for the presentation.

CEROS Program Review - FY94 Research Program
October 16-18, 1995 - List of Reviewers

Mr. Bruce Baxter Enchanted Island Studio 5055 Kikala Road Kalaheo, HI 96740 phone and fax - (808) 332-7676 email - bbaxter@ceros.org	**CAPT R. Jeff LaDouce** Commanding Officer Navy Pacific Meterology & Oceanography Ctr. Box 113 Pearl Harbor, HI 96860-5050 phone - (808) 471-0363 fax - (808) 471-4581 email - ladouce@npmoc.navy.mil
Mr. William A. Friedl Research Administrator CEROS 1001 Bishop Street, Pacific Tower, Suite 2490 Honolulu, HI 96813 phone - (808) 587-5500 fax - (808) 587-5505 email - billf@ceros.org	**Dr. Craig MacDonald** Branch Chief DBEDT - Ocean Resources Branch 737 Bishop Street, Suite 1900 Honolulu, HI 96813 phone - (808) 587-2680 fax - (808) 587-2777 email - oceanorb@pixi.com
Mr. Jeffrey E. Haun Associate Division Head NCCOSC RDTE DIV 5101 49650 Acoustic Road San Diego, CA 92152-6250 phone - (619) 553-5077 fax - (619) 5553-2678 email - haun@nosc.mil	**Ms. Donna Mau** Contracts Administrator High Technology Development Corporation 300 Kahelu Avenue, Suite 35 Mililani, HI 96789 phone - (808) 625-5293 fax - (808) 625-6363 email - donnam@htdc.org
Dr. Tom Kaye Science Advisor CINCPACFLT, Code N8X Pearl Harbor, HI 96860 phone - (808) 471-1496 fax - (808) 471-8687 email - nsapcpf@nosc.mil	**Dr. Barry Raleigh** Dean School of Ocean and Earth Science and Technology - University of Hawaii 1000 Pope Road Honolulu, HI 96822 phone - (808) 956-6182 fax - (808) 956-9152 email - soest@soest.hawaii.edu
Mr. Robert Kihune Executive Director Natural Energy Laboratory of Hawaii Authority P. O. Box 1749 Kailua-Kona, HI 96745 phone - (808) 329-7341 fax - (808) 326-3262 email - nelha@ilhawaii.net	**Dr. J. Richard Seesholtz** Program Manager The Johns Hopkins University Applied Physics Laboratory Johns Hopkins Road Laurel, MD 20723 phone - (703) 516-6026 fax - (703) 516-6065 email - seesholt@bs1.prc.com
Dr. Theo Kooij Program Manager ARPA - Tactical Technology Office 3701 N. Fairfax Drive Arlington, VA 22203-1714 phone - (703) 696-2329 fax - (703) 696-2204 email - tkooij@arpa.mil	

WEDNESDAY, 7 February

0830: Executive Session - Introductions

0930: *LASER HETERODYNE IMAGING FOR SHALLOW WATER SURVEILLANCE*
Varian Associates (Palo Alto, CA)

1030: *DIVER HOMING DEVICE**
Neptune Technologies, Inc. (Kailua, HI)

1130: Lunch

1230: *SWATH MOTION/STRUCTURAL SOFTWARE DEVELOPMENT AND VERIFICATION**
Ocean Engineering Consultants, Inc. (Honolulu, HI)

1330: *HURRICANE RISK ANALYSIS AND MODELING OF COASTAL FLOODING FOR THE HAWAIIAN ISLANDS**
Edward K. Noda and Associates, Inc. (Honolulu, HI)

1430: *OCEAN DOPPLER LIDAR**
Mission Research Corporation (Torrance, CA)

1530: *BIOACTIVE MARINE ISONITRILE COMPOUNDS FROM HAWAIIAN SPONGES AS MODELS FOR SYNTHETIC NONTOXIC ANTIFOULANT AND ANTIBIOTIC AGENTS*
Synthetic Technology Corporation (Honolulu, HI)

1630: Executive Review and Wrap-up

1700: Pau

* "Late Start" Projects

THURSDAY, 8 February

0830: Executive session

0900: *HIGH-RESOLUTION BOTTOM PENETRATING SYNTHETIC APERTURE SONAR USING MULTI-VERTICAL ROW ARRAY AND SUBBOTTOM CLASSIFIER SONAR*
Alliant Techsystems (Mukilteo, WA)

1000: *DUAL MODE FLUORESCENCE IMAGING FOR MARITIME APPLICATIONS*
SETS Technology, Inc. (Mililani, HI)

1100: *DESIGN, CONSTRUCTION AND SEA TRIALS OF A 30-FOOT MANNED TEST MODEL OF A MIDFOIL SWAS*
Pacific Marine & Supply Company, Ltd. (Honolulu, HI)

1200: Lunch

1300: *UNDERWATER ECHOLOCATION FOR OBJECT RECOGNITION, PHASE 3*
ORINCON Hawaii, Inc. (Kailua, HI)

1400: *ADVANCED REAL-TIME MULTIFUNCTIONAL SIGNAL PROCESSOR*
ORINCON Hawaii, Inc. (Kailua, HI)

1500: Executive Review and Wrap-up

1600: Pau

<u>Notes:</u>

⇒ Presentations will be made in the Conference Room at the CEROS Office.

⇒ Each presentation will begin either on the half-hour or the hour, as appropriate, and end 50 minutes later.

⇒ Each presentation will include up to 25 minutes of technical overview followed by up to 25 minutes of Q&A/discussion.

⇒ The technical overview will include the FY95 project **Objectives**, **Expected Products** or **Results**, and **Budget** and will specify the project's **Principal Technical Risks**, **Innovation**, and **Schedule**.

⇒ Each presentation team will be limited to 3 people, maximum. The project's Principal Investigator will be responsible for the presentation.

CEROS Program Review - FY95 Research Program
February 7-8, 1996 - List of Reviewers

Mr. Bruce Baxter Enchanted Island Studio 5055 Kikala Road Kalaheo, HI 96740 phone and fax - (808) 332-7676 email - bbaxter@ceros.org	**CAPT R. Jeff LaDouce** Commanding Officer Navy Pacific Meterology & Oceanography Ctr. Box 113 Pearl Harbor, HI 96860-5050 phone - (808) 471-0363 fax - (808) 471-4581 email - ladouce@npmoc.navy.mil
Mr. William A. Friedl Research Administrator CEROS 1001 Bishop Street, Pacific Tower, Suite 2490 Honolulu, HI 96813 phone - (808) 587-5500 fax - (808) 587-5505 email - billf@ceros.org	**Dr. Craig MacDonald** Branch Chief DBEDT - Ocean Resources Branch 737 Bishop Street, Suite 1900 Honolulu, HI 96813 phone - (808) 587-2680 fax - (808) 587-2777 email - oceanorb@pixi.com
Mr. Jeffrey E. Haun Associate Division Head NCCOSC RDTE DIV 5101 49650 Acoustic Road San Diego, CA 92152-6250 phone - (619) 553-5077 fax - (619) 5553-2678 email - haun@nosc.mil	**Ms. Donna Mau** Contracts Administrator High Technology Development Corporation 300 Kahelu Avenue, Suite 35 Mililani, HI 96789 phone - (808) 625-5293 fax - (808) 625-6363 email - donnam@htdc.org
Dr. Tom Kaye Science Advisor CINCPACFLT, Code N8X Pearl Harbor, HI 96860 phone - (808) 471-1496 fax - (808) 471-8687 email - nsapcpf@nosc.mil	**Dr. Barry Raleigh** Dean School of Ocean and Earth Science and Technology - University of Hawaii 1000 Pope Road Honolulu, HI 96822 phone - (808) 956-6182 fax - (808) 956-9152 email - soest@soest.hawaii.edu
Mr. Robert Kihune Executive Director Natural Energy Laboratory of Hawaii Authority P. O. Box 1749 Kailua-Kona, HI 96745 phone - (808) 329-7341 fax - (808) 326-3262 email - nelha@ilhawaii.net	**Dr. J. Richard Seesholtz** Program Manager The Johns Hopkins University Applied Physics Laboratory Johns Hopkins Road Laurel, MD 20723 phone - (703) 516-6026 fax - (703) 516-6065 email - seesholt@bs1.prc.com
Dr. Theo Kooij Program Manager ARPA - Tactical Technology Office 3701 N. Fairfax Drive Arlington, VA 22203-1714 phone - (703) 696-2329 fax - (703) 696-2204 email - tkooij@arpa.mil	

CEROS FY95 Core Program Review: **SCHEDULE**

Wednesday, October 30th

0830 ***LASER HETERODYNE IMAGING FOR SHALLOW WATER SURVEILLANCE***
Varian Associates (Palo Alto, CA)
M. Leonard Riaziat, Principal Investigator

0930 ***OCEAN DOPPLER LIDAR***
Mission Research Corporation (Torrance, CA)
Jerry Butman, Principal Investigator

1030 ***DUAL MODE FLUORESCENCE IMAGING FOR MARITIME APPLICATIONS***
SETS Technology, Inc. (Mililani, HI)
Gregory Mooradian, Principal Investigator

1130 Lunch

1300 ***SWATH MOTION/STRUCTURAL SOFTWARE DEVELOPMENT AND VERIFICATION***
Ocean Engineering Consultants, Inc. (Honolulu, HI)
Ludwig H. Seidl, Principal Investigator

1400 ***MODELING OF HURRICANE-INDUCED COASTAL FLOODING FOR THE HAWAIIAN ISLANDS***
Edward K. Noda & Associates, Inc. (Honolulu, HI)
Edward K. Noda, Principal Investigator

1500 ***DESIGN, CONSTRUCTION AND SEA TRIALS OF A 30-FOOT MANNED TEST MODEL OF A MIDFOIL SWAS***
Pacific Marine & Supply Company, Ltd. (Honolulu, HI)
Steven Loui, Principal Investigator

Thursday, October 31st

0900 ***HIGH-RESOLUTION BOTTOM PENETRATING SYNTHETIC APERTURE SONAR USING MULTI-VERTICAL ROW ARRAY AND SUBBOTTOM CLASSIFIER SONAR***
Alliant Techsystems (Mukilteo, WA)
Dennis J. Garrood and Mark L. Neudorfer, Principal Investigators

1000 ***UNDERWATER ECHOLOCATION FOR OBJECT RECOGNITION, PHASE 3***
ORINCON Hawaii, Inc. (Kailua, HI)
Gerald C. Moons, Principal Investigator

1100 ***DIVER HOMING DEVICE***
Neptune Technologies, Inc. (Kailua, HI)
Jack E. Holzschuh, Principal Investigator

1200 Lunch

1330 ***NATURALLY-OCCURRING ANTIBACTERIAL AND ANTIFUNGAL SUBSTANCES FROM MARINE ALGAE CHAETOCEROS, NITZSCHIA AND THALASSIOSIRA***
Aquaculture Technology, Inc. (Honolulu, HI)
Jaw-Kai Wang, Principal Investigator

1430 ***BIOACTIVE MARINE ISONITRILE COMPOUNDS FROM HAWAIIAN SPONGES AS MODELS FOR SYNTHETIC NONTOXIC ANTIFOULANT AND ANTIBIOTIC AGENTS***
Synthetic Technology Corporation (Honolulu, HI)
Mark R. Hagadone, Principal Investigator

1530 Wrap-up

CEROS Program Review - FY95 Research Program
October 30-31, 1996 - List of Reviewers

Mr. Bruce Baxter President Enchanted Island Studio 5055 Kikala Road Kalaheo, HI 96740 phone and fax - (808) 332-7676 email - bbaxter@ceros.org	**Dr. Theo Kooij** Program Manager ARPA - Tactical Technology Office 3701 N. Fairfax Drive Arlington, VA 22203-1714 phone - (703) 696-2333 fax - (703) 696-2204 email - tkooij@arpa.mil
Mr. Tom Casey Science Advisor COMMANDER Force US Pacific 1001 Morton Street, Building 619 Pearl Harbor, HI 96860-6550 phone - (808) 474-5651 fax - (808) 422-6536 email - nsapcsp@nimo.nosc.mil	**Ms. Donna Mau** Contracts Administrator CEROS 1001 Bishop Street Pacific Tower, Suite 2490 Honolulu, HI 96813 phone - (808) 587-5500 fax - (808) 587-5505 email - donnam@ceros.org
Dr. Jerry Dobeck Coastal Systems Station Dahlgren Division, Code R12 6703 W. Highway 98 Panama City, FL 32407 phone - (904) 234-4222 fax - (904) 235-5374 email - dobeck@atcf.ncsc.navy.mil	**Mr. Doug Murphy** COMMANDING OFFICER NCCOSC RDTE DIV 37 53475 Strothe Road, Room 227 San Diego, CA 92152-6343 phone - (619) 553-5838 fax - (619) 553-6356 email - murphy@nosc.mil
Mr. William A. Friedl Technical Director CEROS 73-4460 Queen Kaahumanu Hwy., Suite 111 Kailua-Kona, HI 96740 phone - (808) 327-3350 fax - (808) 327-3355 email - billf@ceros.org	**Dr. Paul Rispin** Office of Naval Research Code 362 800 N. Quincy Street Arlington, VA 22217-5660 phone - (703) 696-0339 fax - (703) 696-4884 email - rispinp@onrhq.onr.navy.mil
Mr. Brian Guimond Tactical Analysis Director COMMANDER Force US Pacific 1001 Morton Street, Code N72 Pearl Harbor, HI 96860-6550 phone - (808) 471-2639 fax - (808) 422-6536 email - guimond@nosc.mil	**Dr. J. Richard Seesholtz** Program Manager The Johns Hopkins University Applied Physics Laboratory Johns Hopkins Road Laurel, MD 20723 phone - (703) 516-6026 fax - (703) 516-6065 email - seesholt@bs1.prc.com
Mr. Robert Kihune Chief Executive Officer Waimana Kaiser Enterprises 1001 Bishop Street Pauahi Tower, Suite 1520 Honolulu, HI 96813 phone - (808) 599-4441 fax - (808) 599-4653 email - waimana@aol.com	**Dr. Ace Summey** Division Head Coastal Systems Station Dahlgren Division, Code 01DU 6703 W. Highway 98 Panama City, FL 32407 phone - (904) 234-4472 fax - (904) 234-4133 email - summey_delbert@lanmail.ncsc.navy.mil

CEROS FY96 CORE PROGRAM REVIEW - NELH, KAILUA-KONA, HAWAII

WEDNESDAY, 5 FEBRUARY

0830 EXECUTIVE SESSION
0930 *ADVANCED REAL-TIME SENSOR (ARTS) UPGRADE*
ORINCON Hawaii, Inc.
1030 *SUBMARINE-LAUNCHED, TWO-WAY FIBER OPTICS-LINKED COMMUNICATIONS BUOY*
ORINCON Corporation
1130 LUNCH
1230 *FINITE ELEMENT DESIGN OF CABLES*
Knapp Engineering, Inc.
1330 *LOOP AVOIDANCE CONTROL DURING THE DEPLOYMENT AND RETRIEVAL OF SUBMARINE CABLES*
Makai Ocean Engineering, Inc.
1430 *DEVELOPMENT AND TESTING OF A CLATHRATE DESALINATION RESEARCH FACILITY*
Thermal Energy Storage, Inc.
1530 *HIGH-RESOLUTION BOTTOM PENETRATING SYNTHETIC APERTURE SONAR FOR USE IN BURIED UXO HUNTING*
Alliant Techsystems, Inc.
1630 EXECUTIVE REVIEW / WRAP-UP
1700 *PAU*

THURSDAY, 6 FEBRUARY

0830 EXECUTIVE SESSION
0900 *BIOACTIVE MARINE ISONITRILE COMPOUNDS FROM HAWAIIAN SPONGES AS MODELS FOR SYNTHETIC NONTOXIC ANTIFOULANT AND ANTIBIOTIC AGENTS II. SYNTHETIC ANALOGS, PAINT FORMULATIONS, AND MECHANISMS OF ACTION*
Synthetic Technology Corp.
1000 *GRAZING ANGLE IMAGING LIDAR FOR ORGANIC MINE COUNTERMEASURES*
SETS Technology, Inc.
1100 *DUAL MODE FLUORESCENCE IMAGING FOR MARITIME APPLICATIONS: PHASE II*
SETS Technology, Inc.
1200 LUNCH
1300 *DEVELOPMENT OF AN UNDERWATER VIDEO CAMERA FOR OPTICAL CONTRAST AND RANGE ENHANCEMENT USING SPECTRAL STRETCHING*
TerraSystems, Inc.
1400 *FLOW SIMULATION AND VISUALIZATION FOR SWATH SHIPS*
Ocean Engineering Consultants, Inc.
1500 *SOLUTION PLUS IN-SITU OCEAN SEDIMENT CHEMICAL ANALYZER*
Detection Limit Technology, Inc.
1600 EXECUTIVE REVIEW / WRAP-UP
1700 *PAU*

FYI: Instructions sent to each Principal Investigator:

The following guidance applies to your presentation at the review:

- Presentations will be made in the Main Conference Room at the Natural Energy Laboratory of Hawaii facility, Keahole Point.
- Each presentation will begin on the half-hour or the hour, as indicated, and end 50 minutes later. You can wait at the CEROS Project Office on the second floor of the NELHA Administration Building before your presentation.
- You should plan your presentation to include about 25 minutes of technical overview followed by up to 25 minutes of questions and discussion.
- Your presentation's technical overview should include the project's **Objectives**, **Expected Products** or **Results**, and **Budget** and should provide specific information on the project's **Principal Technical Risks**, **Innovation**, and **Schedule**.
- Please bring a hard copy of your presentation for retention at the CEROS office.
- As the project's principal investigator, you are responsible for the presentation. Team presentations are permitted. Please let us know how many people will be with you at the review and if you have any particular presentation requirements.

CEROS Program Review - FY 96 Research Program
February 5-6, 1997 - List of Reviewers

Mr. John Ablard Deputy Director Defense Advanced Research Projects Agency Contracts Management Office 3701 North Fairfax Drive Arlington, VA 22203-1714 phone - (703) 696-2383 fax - (703) 696-2208 email - jablard@darpa.mil	**Dr. James D. DeCorpo** Associate Technical Director for Development Office of Naval Research 800 North Quincy Street, Code O1B Arlington, VA 22217-5660 phone - (703) 696-1300 fax - (703) 696-4065 email - decorpj@onrhq.onr.navy.mil
Mr. Bruce Baxter **CEROS RAB** President Enchanted Island Studio 5055 Kikala Road Kalaheo, HI 96740 phone and fax - (808) 332-7676 email - bruce@hawaiian.net	**Mr. William A. Friedl** Technical Director CEROS 73-4460 Queen Kaahumanu Highway, # 111 Kailua-Kona, Hawaii 96740 phone - (808) 327-3350 fax - (808) 327-3355 email - billf@ceros.org
Mr. Duncan Brown Science Advisor CINCPACFLT Code N8X 250 Makalapa Drive Pearl Harbor, Hawaii 96860 phone - (808) 471-1496 fax - (808) 471-5856	**Mr. Jeffrey E. Haun** **CEROS RAB** Head, Biosciences Division NCCOSC RDT&E DIV D35 53560 Hull Street San Diego, CA 92152-5001 phone - (619) 553-5077 fax - (619) 553-2678 email - haun@nosc.mil
Dr. Steve Cowen Branch Head Advanced Concepts Branch NCCOSC RDT&E DIV D746 San Diego, CA 92152-5000 phone - (619) 553-1954 fax - (619) 553-6340 email - cowen@nosc.mil	**Mr. Robert K. U. Kihune** **CEROS RAB** Chief Executive Officer Waimana Kaiser Enterprises 1001 Bishop Street Pauahi Tower, Suite 2750 Honolulu, Hawaii 96813 phone - (808) 599-4441 fax - (808) 599-4653 email - waimana@aol.com
Mr. Dan Curran, J.D. CEROS Consultant Senior Research Fellow Marine Policy Center Woods Hole Oceanographic Institution Woods Hole, MA 02543-1138 phone - (508) 289-2496 fax - (508) 457-2184 email - dcurran@whoi.edu	**Dr. Theo Kooij** Program Manager Defense Advanced Research Projects Agency Tactical Technology Office 3701 North Fairfax Drive Arlington, VA 22203-1714 phone - (703) 696-2333 fax - (703) 696-2204 email - tkooij@darpa.mil
Dr. Thomas H. Daniel **CEROS RAB** Scientific/Technical Director Acting Executive Director Natural Energy Laboratory of Hawaii Authority 73-4460 Queen Kaahumanu Highway # 101 Kailua-Kona, Hawaii 96740 phone - (808) 329-7341 fax - (808) 326-3262 email - nelha@ilhawaii.net	**Dr. Craig MacDonald** **CEROS RAB** Branch Chief DBEDT - Ocean Resources Branch P. O. Box 2359 Honolulu, Hawaii 96804 phone - (808) 587-2680 fax - (808) 587-2777 email - cmacdona@dbedt.hawaii.gov

Ms. Donna Mau Contracts & Grants Administrator CEROS Contracts Office 1001 Bishop Street Pacific Tower, Suite 2490 Honolulu, Hawaii 96813 phone - (808) 587-5500 fax - (808) 587-5505 email - donnam@ceros.org	**Dr. Richard Seesholtz** Program Manager The Johns Hopkins University Applied Physics Laboratory Johns Hopkins Road Laurel, MD 20723 phone - (703) 516-6026 fax - (703) 516-6065 email - seesholt@bs1.prc.com
Mr. Henry Scheetz Deputy Director Department of the Navy Airborne Mine Countermeasures, PM S210B 2531 Jefferson Davis Highway Arlington, Virginia 22242 phone - (703) 602-5095 fax - (703) 602-5105 email - scheetz_henry_a@hq.navsea.navy.mil	**Mr. George Wilkins** CEROS Advisor 73-1410-A Kaloko Drive Kailua-Kona, HI 96740 phone - (808) 325-6116 fax - (808) 329-7585
	Mr. Mason Young Administrator Department of Land & Natural Resources Land Management Division P. O. .Box 621 Honolulu, Hawaii 96809 phone - (808) 587-0388 fax - (808) 587-0311

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